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Technical Report CERC-93-6
April 1993

US Army Corps
of Engineers
Waterways Experiment
Station

Observations and Modelling of Winds and Waves During the Surface Wave Dynamics Experiment

Report 1
Intensive Observation Period IOP-1
20–31 October 1990

by *Michael J. Caruso*
Woods Hole Oceanographic Institution

Hans C. Graber
University of Miami

Robert E. Jensen
Coastal Engineering Research Center

Mark A. Donelan
Canada Centre for Inland Waters

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Prepared for Headquarters, U.S. Army Corps of Engineers

Under Upgrading of Discrete Spectral Hindcasting Models
Work Unit 32523
Office of Naval Research Contracts N00014-90-J-1464,
N00014-92-J-1546, and N00014-88-J-1028

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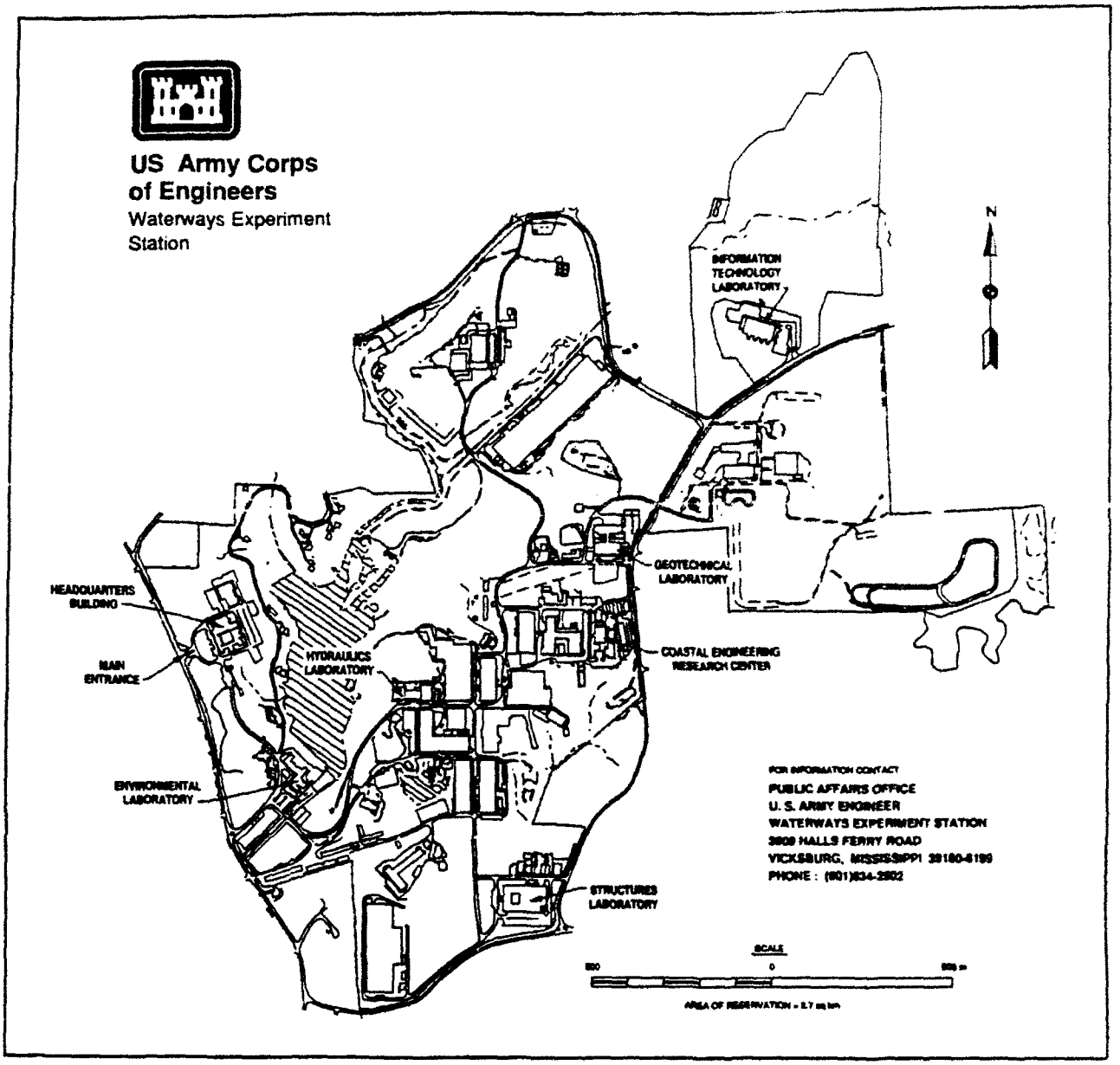

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Preface

The authors gratefully acknowledge funding support by the Small-Scale Physics Program (Code 1122SS) at the Office of Naval Research (ONR) under Grant Nos. N00014-90-J-1464, N00014-92-J-1546, and N00014-88-J-1028. Support for shiptime of the R/V *Oceanus* was pooled and provided by Codes 1122SS and 1125OA at ONR.

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1 Introduction

The primary scientific goals of the Surface Wave Dynamics Experiment (*SWADE*) are to understand the dynamics of the evolution of the directional wind-wave spectrum and the effect of waves on fluxes of momentum, heat and mass at the air-sea interface. A detailed discussion of the scientific and experimental objectives as well as a description of the measurement systems and sensors can be found in Weller *et al.* (1991). The experiment began on October 1, 1990 and lasted for a six-month period in the waters off the DelMarVa Peninsula. During three intensive observation periods (IOPs) the in-situ measurements from buoys were complemented by radar and remote sensing observations from aircraft and a ship.

An improved understanding of the evolution of the directional wave spectrum under a variety of spatially and temporally inhomogeneous wind fields will make it possible to determine and develop better parameterizations of the source term physics in numerical wind-wave models. Unlike previous field experiments (e.g. JONSWAP, ARSLOE) *SWADE* will provide wind data from a spatially dense array of buoys, which were deployed between Cape Hatteras and Cape Cod. The wind forcing field still remains the largest source of error in our capability to predict the directional wave field and hence the sea state. An improved specification of the wind field will be suitable for examining the physics of the source functions for wind energy input, nonlinear wave-wave interactions and dissipation by breaking.

Buoy measurements are summarized in Chapter 2. A brief description of the third-generation wave model (WAM) model is given in Chapter 3; the model domains used during *SWADE* are discussed in Chapter 4; the six wind fields are briefly described in Chapter 5; the model currents are described in Chapter 6; and finally some details of the first Intense Observation Period (IOP-1) are presented in Chapter 7. The appendices will present time series of meteorological and wave parameters, plots of directional wave spectra, maps of wind vector fields and the associated wave hindcasts, and maps of the modelled surface current fields.

2 Buoy Measurements

SWADE buoys

In addition to the existing operational network of buoys maintained by the National Data Buoy Center (NDBC), *SWADE* deployed two 3-m discus buoys with several modifications to their measuring capability (Figure 1), four MiniMet meteorological buoys (Figure 2), and one WAVESCAN directional wave buoy provided by SEATEX, Norway (Figure 3). The modified Mills-cross array was designed to provide spatial estimates of the variation in wave, wind, and flux data. At its center was the Brookhaven Spar buoy (Figure 4) which was instrumented with a centered pentagon wave gage array to measure high resolution directional wave spectra. Unfortunately, the Spar buoy sank after the peak of the October Storm on October 26, 1990. The Spar buoy was replaced by another 3-m discus buoy provided by NDBC and by the SWATH (Small Water Plane Area - Twin Hull) ship, *Frederick G. Creed*, from the Canadian Department of Fisheries and Oceans. The SWATH was used as a mobile research platform and with its special equipment could perform almost all tasks expected of the Spar (Donelan *et al.* 1992). The U.S. Army Engineer Waterways Experiment Station Coastal Engineering Research Center (CERC) and the Woods Hole Oceanographic Institution (WHOI) also contributed to *SWADE*, each providing a 3-m discus buoy. Figure 5 shows the locations of the *SWADE* experimental measurement array. Table 1 summarizes the deployment logistics for these buoys. Most buoys were deployed by the end of September from R/V *Oceanus*.

Table 1
Deployment positions and logistics for *SWADE* buoys.

Station	WMO Code	Latitude	Longitude	Depth	Comments
Spar		37° 30.1' N	74° 21.5' W	200 m	Sank on 10-26-90 Recoverd in June 1992
D-East	44015	37° 06.8' N 37° 29.0' N	73° 36.9' W 73° 23.9' W	2,790 m 2,469 m	Adrift on 1-19-91 Reset on 1-24-91
D-North	44001	38° 42.1' N	73° 33.5' W	115 m	
D-Central	44023	37° 32.1' N	74° 23.5' W	102 m	Replaced Spar
MET-1	41012 41014	35° 15.0' N	70° 00.0' W	4,572 m	Adrift on 10-3-90 Recovered 4-5-91
MET-2	44018 44022	37° 41.3' N	74° 43.2' W	49 m	Adrift on 10-27-90 ARGOS lost on 11-12-90
MET-3	44016 44020	37° 59.9' N	72° 54.7' W	2,617 m	Equipped with Wotan
MET-4	44017 44021	40° 06.1' N	72° 14.3' W	77 m	Adrift on 11-19-90 Recovered 5-28-91
CERC	44014	36° 35.0' N	74° 50.0' W	48 m	
WAVESCAN		38° 56.8' N	73° 10.8' W	79 m	GOES stops on 1-29-91
IMET		37° 25.0' N	73° 48.0' W	2,101 m	Damaged on 10-26-90

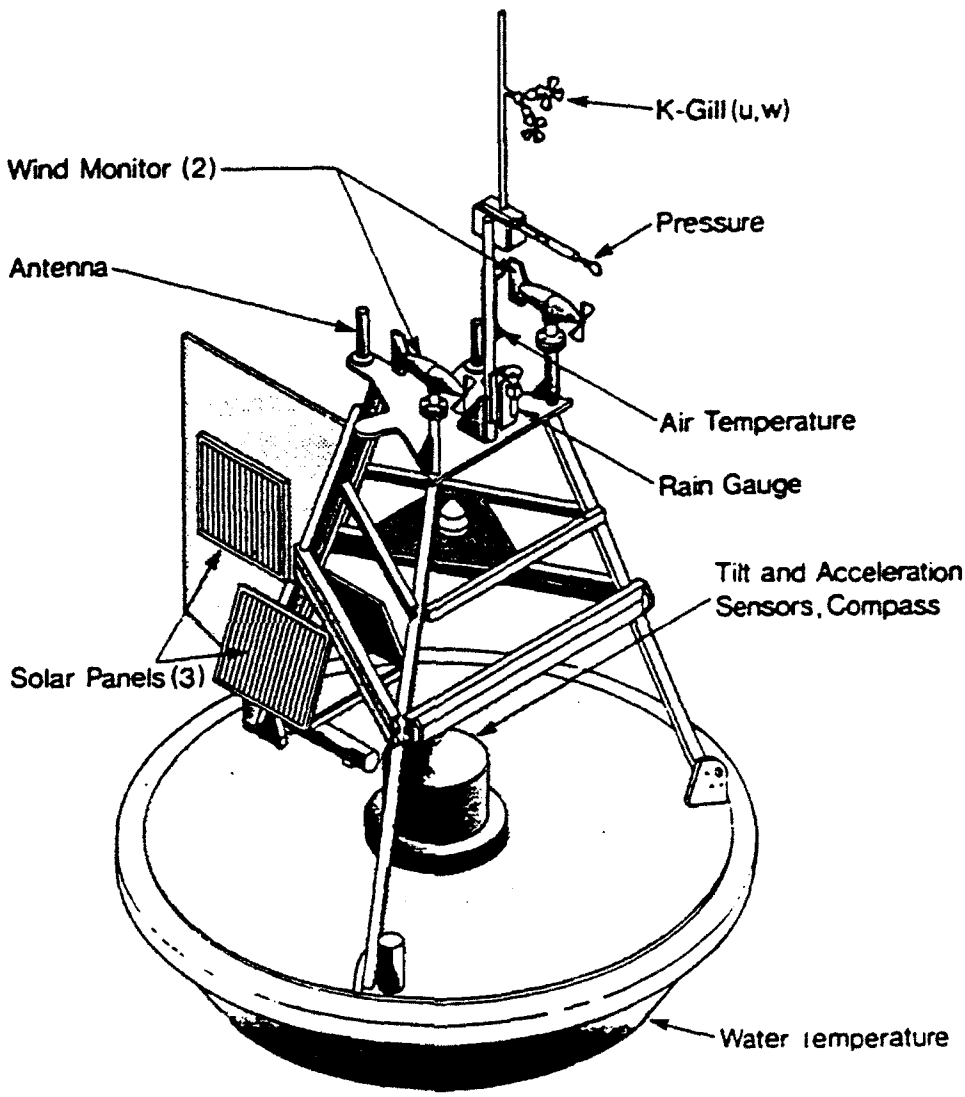

Figure 1: A modified SWADE/NDBC 3-m discus buoy.

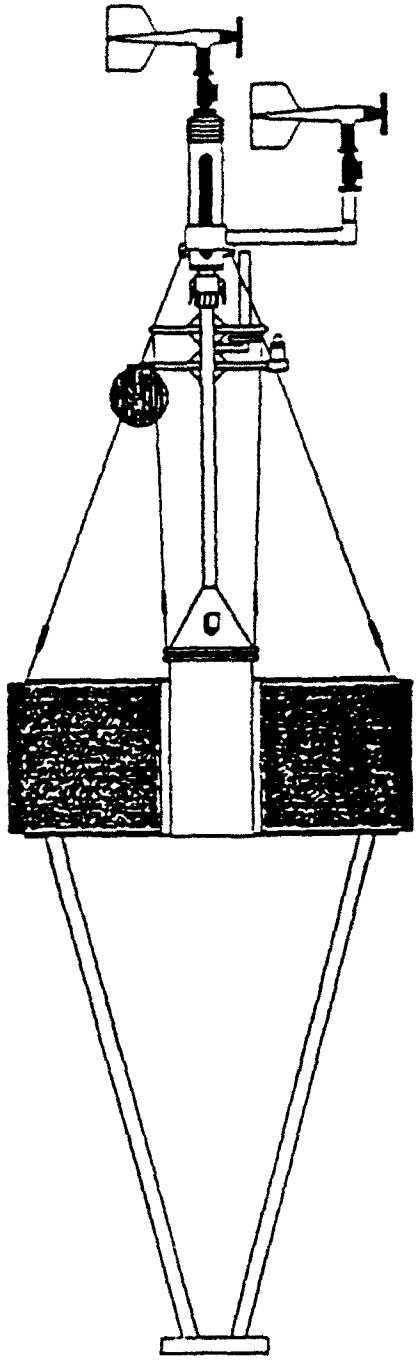

Figure 2: A modified SWADE/MiniMet buoy.

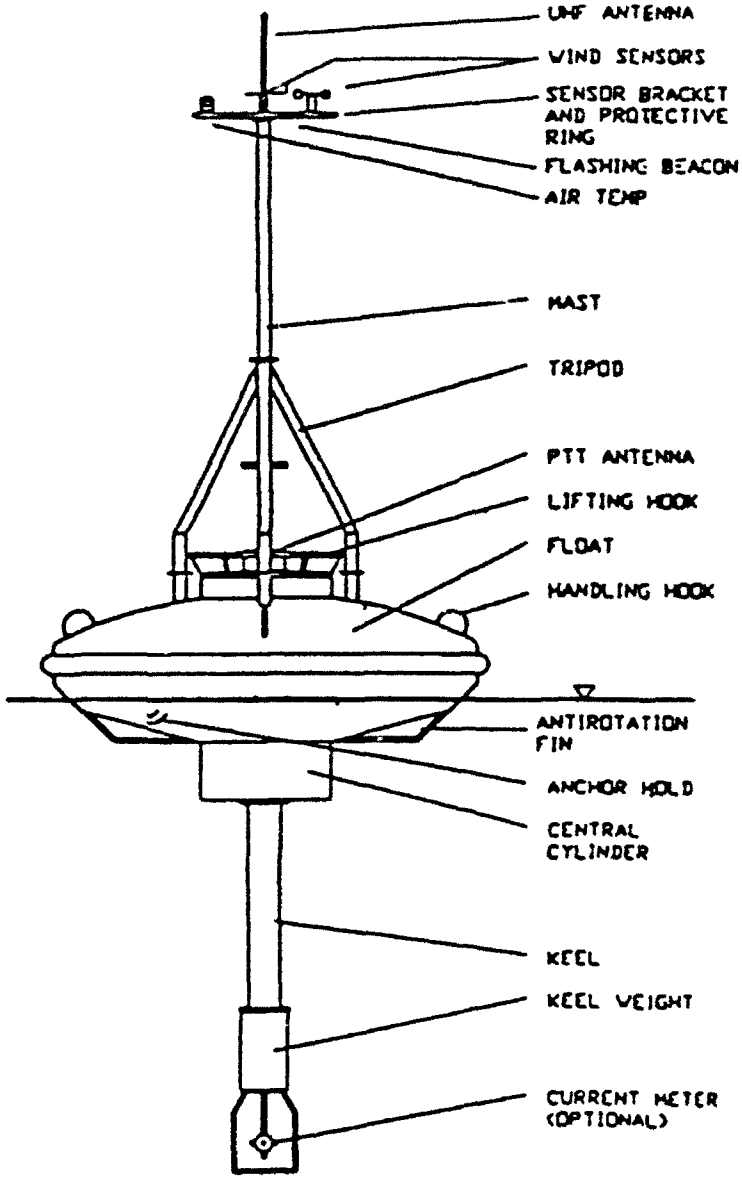

Figure 3: A WAVESCAN directional wave buoy.

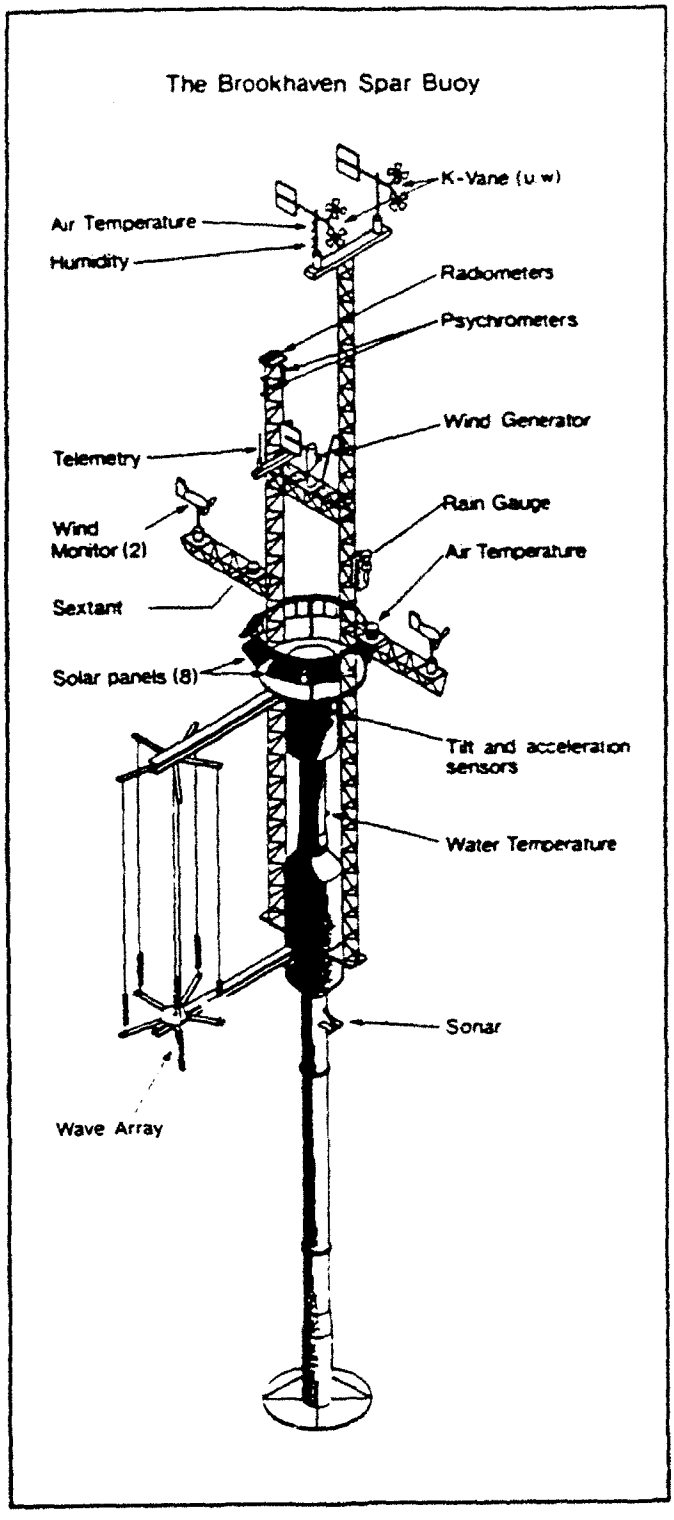

Figure 4: The length of the spar measures 30 m from the K-vane anemometers to the bottom drag plates. The K-vanes are installed at a height of 10 m and the wind anemometers are at 6 m. The wire wave gauges measure 6 m in length.

Data from the buoys listed above as well as all NDBC buoys and C-MAN stations along the East Coast (Figure 6) are available for the entire *SWADE* experimental period and have been archived at the National Aeronautics and Space Administration (NASA)/Wallops Data Archive Center (Oberholtzer and Donelan 1993). The NDBC portion of the buoy instrumentation transmits hourly values of wind speed and direction (two sensors), atmospheric pressure, air and water temperature, significant wave height, average and dominant wave period. In addition, the covariance spectra for directional wave data as a function of frequency are also transmitted. The Canada Centre for Inland Waters (CCIW) motion sensor packages and K-Gill anemometers sampled data continuously at 1 Hz and stored the data internally on five 120-Mbyte laser disks. A summary of the sampling interval, recording period and system accuracy is presented in Table 2. For details on the buoy sensors and calibration procedures, the reader is referred to Steele, Teng, and Wang (1992).

In Appendix A, time history plots of wind speed and direction, significant wave height, peak wave period, atmospheric pressure, air and sea temperature are presented for IOP-1 from *SWADE* buoys D-East and D-North and CERC (44014). In addition, time series of these variables are also shown for buoys 41001, 44004, 44008, 44009, 44011, 44012 and the C-MAN stations DSLN7, CHLV2 and BUZM3.

In Appendix B, plots of the directional wave spectra and the associated one-dimensional frequency spectra are presented for buoys D-East, D-North and CERC (44014) every 3 hr from 24 October 1990, 03:00 GMT to 29 October 1990, 00:00 GMT during IOP-1. The directional wave spectra were computed with a maximum-likelihood technique described in Drennan, Graber, and Donelan (1993). Note there are several data gaps for buoy D-North.

Table 2
Measurement characteristics of meteorological variables on NDBC 3-m discus buoys (after Steele et al. 1992).

Parameter	Range	Resolution	Sample interval	Sample period	Total system accuracy
Wind speed	0-80 ms^{-1}	0.1 ms^{-1}	1 sec	8 min	± 1 ms^{-1} or 10%
Wind direction	0-360°	1°	1 sec	8 min	$\pm 10°$
Wind gust*	0-80 ms^{-1}	0.1 ms^{-1}	1 sec	5 sec	± 1 ms^{-1} or 10%
Air temperature	-40 to 50 °C	0.5 °C	90 sec	90 sec	± 1°C
Sea surface temperature	-15 to 50 °C	0.5 °C	1 sec	1 sec	± 1°C
Barometric pressure	900-1100 hPa (mb)	0.1 hPa (mb)	4 sec	8 min	± 1hPa (mb)

* Highest 5-sec window average

Meteorological buoys

Four modified MiniMet buoys were deployed to improve the capability to measure the spatial mesoscale variability in the wind field. These buoys were placed along the axes of the modified Mills-cross to increase the number of spatial lags for the wind measurements both along west-east and south-north directions. Unfortunately, the environmental harshness

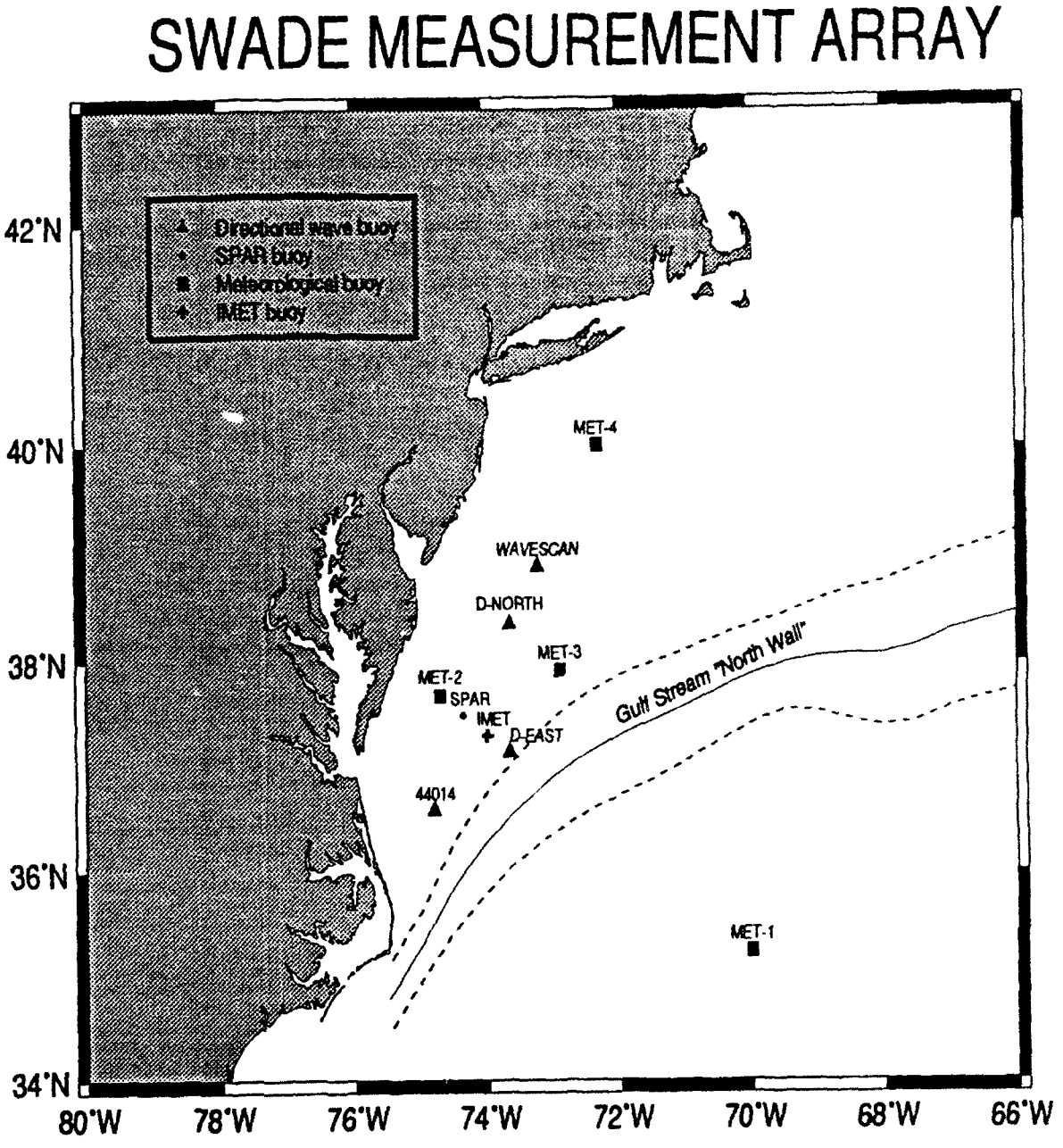

Figure 5: Geographic location of the *SWADE* program and the positions of the buoys during IOP-1. The mean (solid) and one standard deviation (dashed) positions of the "North Wall" of the Gulf Stream are also shown.

NDBC AND SWADE BUOY LOCATIONS

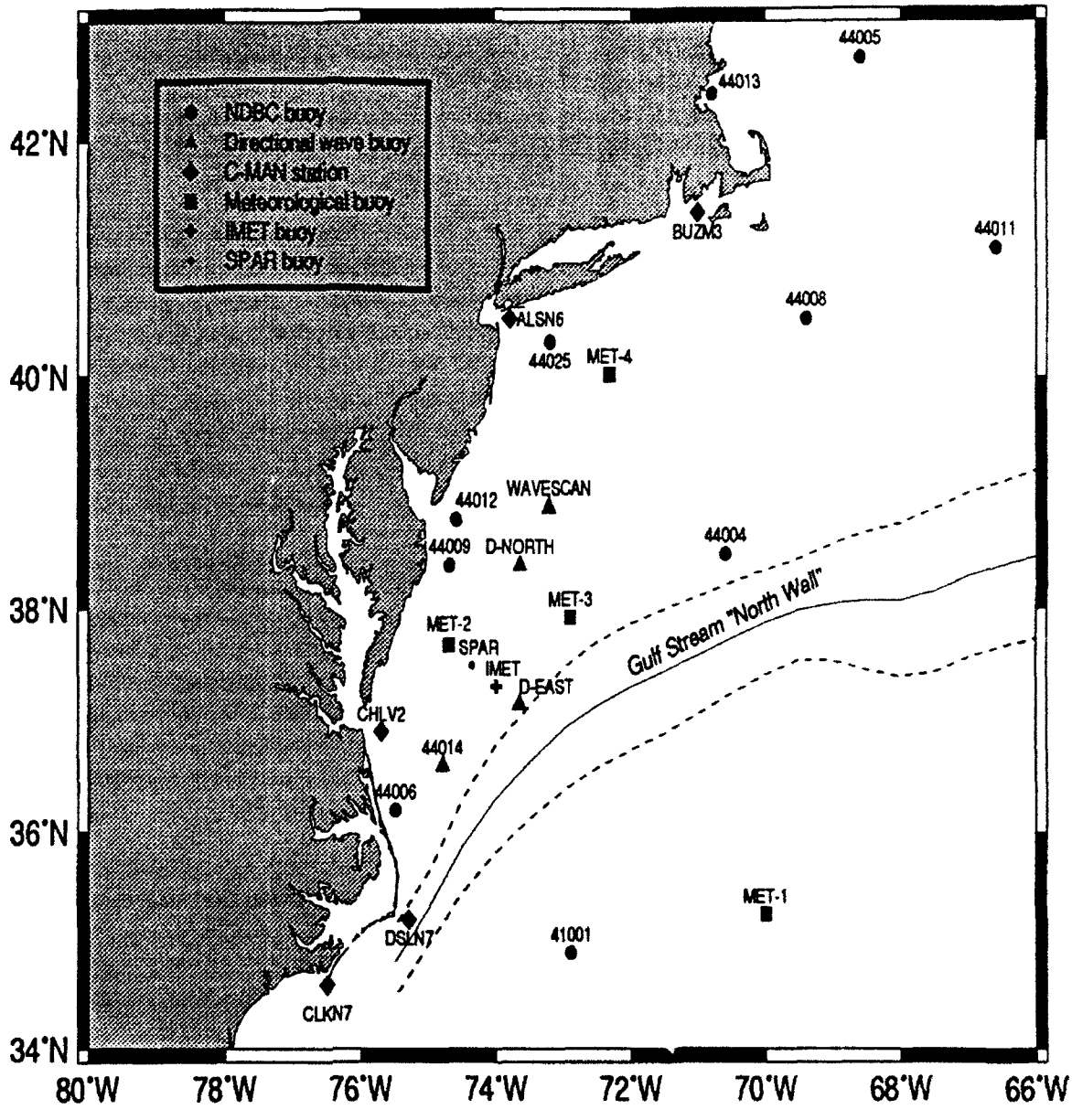

Figure 6: Geographic location of the *SWADE* buoys embedded within the network of buoys and C-MAN stations maintained by the NDBC. The mean (solid) and one standard deviation (dashed) positions of the "North Wall" of the Gulf Stream are also shown.

during the fall and winter months forced three of these buoys to move and remain adrift. *MET-3* was the only buoy to remain stationary for the entire experiment.

Shortly after its deployment *MET-1* began to move as a result of an eddy. The buoy drifted southwestward from its original position and reanchored itself at around 33° 56' N and 72° 14' W. Around the middle of January the buoy began to drift again initially in a southeasterly direction, but later changed course and turned back towards the southwest. According to Advanced Very High Resolution Radiometer (AVHRR) imagery, a cold core ring located in this region appeared to influence the buoy. It reattached itself to the bottom around 32° 38' N and 73° 57' W. In the beginning of April 1991 the buoy was successfully recovered by the R/V *Cape Henlopen*. Figure 7 shows the track of the buoy from deployment to recovery.

MET-2 was located in shallow water just offshore from Wallops Island. Both wind anemometers were damaged shortly after deployment, but spare sensors were installed during a second deployment cruise. During the *SWADE* October storm the buoy was set in motion due to intense wind and wave forcing. The initial course was south towards the CERC buoy 44014. At this time the Gulf Stream was in close proximity to Cape Hatteras and finally engulfed the buoy and quickly transported it northeastward. ARGOS contact was lost on November 12, 1990. Although several more signals were received at later dates, their sparsity made it impossible to determine the buoy's position uniquely. At this time *SWADE* researchers assume that the buoy has been lost. Figure 8 depicts the buoy's course until ARGOS transmission ceased.

MET-4 was located southeast off Long Island. It is not yet apparent what set the buoy in motion around November 19, 1990. There was an intense storm (cold-air outbreak) passing over the region, but winds and waves were not intense enough to shift the buoy from its anchored location. With the southward flowing coastal current the buoy drifted towards Cape Hatteras where it was caught by the Gulf Stream. Figure 9 shows the curious and sometimes erratic path of the buoy. There is evidence from AVHRR imagery that this track resembles some of the dynamics of the Gulf Stream. The buoy was recovered from the icy waters of the Labrador Sea by the USCG *Bittersweet* on May 28, 1991.

In Appendix C, time history plots of wind speed and direction, air and sea temperature and atmospheric pressure are shown for all four MET buoys. Note that the measurement height of the wind sensors on the MiniMet buoys were about 2.7 m above the mean sea surface.

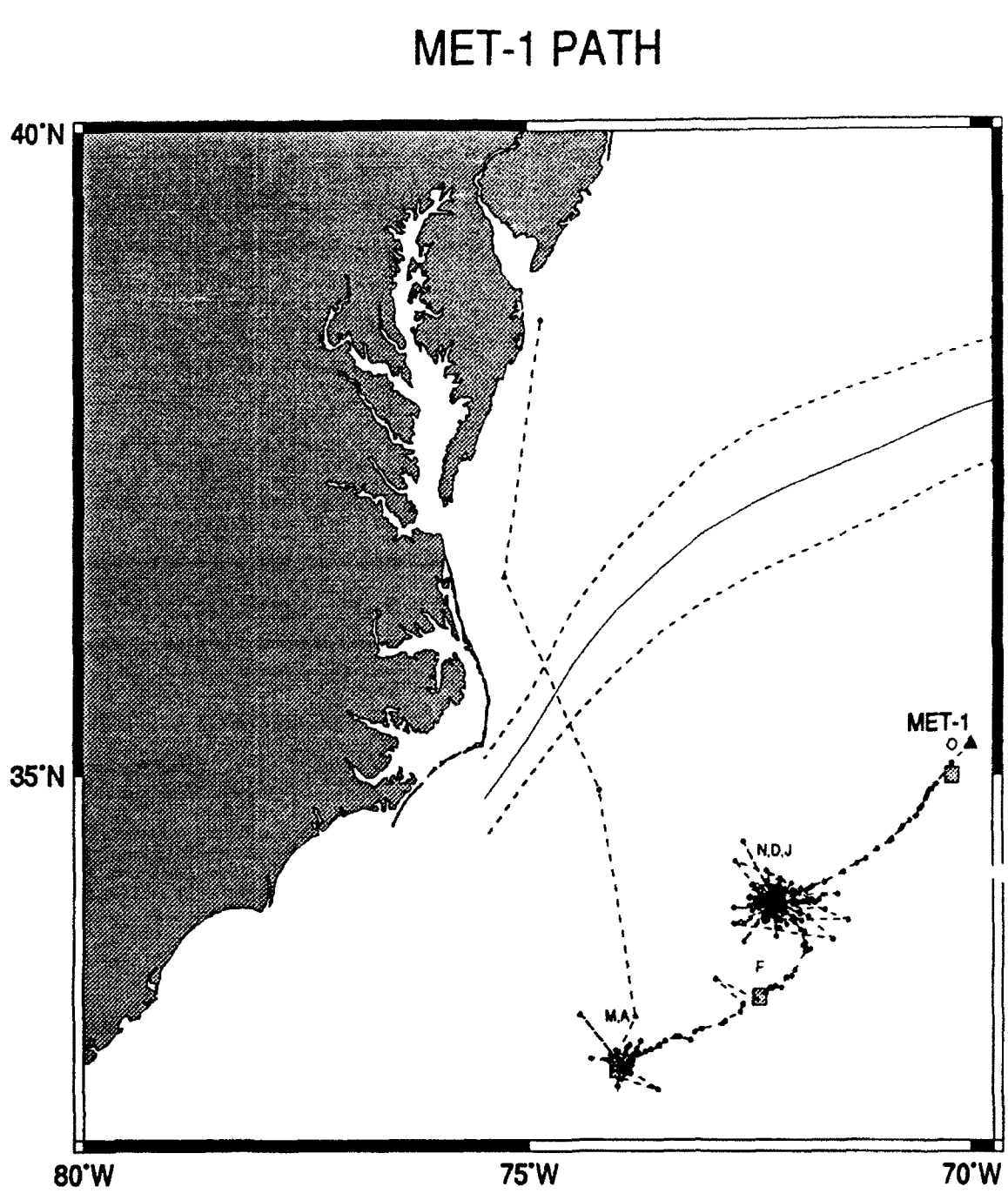

Figure 7: Drift track of MET-1 from September 1990 to April 1991. Each dot corresponds approximately to a daily position transmitted via ARGOS. The mean (solid) and one standard deviation (dashed) positions of the "North Wall" of the Gulf Stream are also shown. Note, shaded squares mark the position at the beginning of each month identified by letters (O = OCT, N = NOV, D = DEC, J = JAN, F = FEB, M = MAR and A = APR).

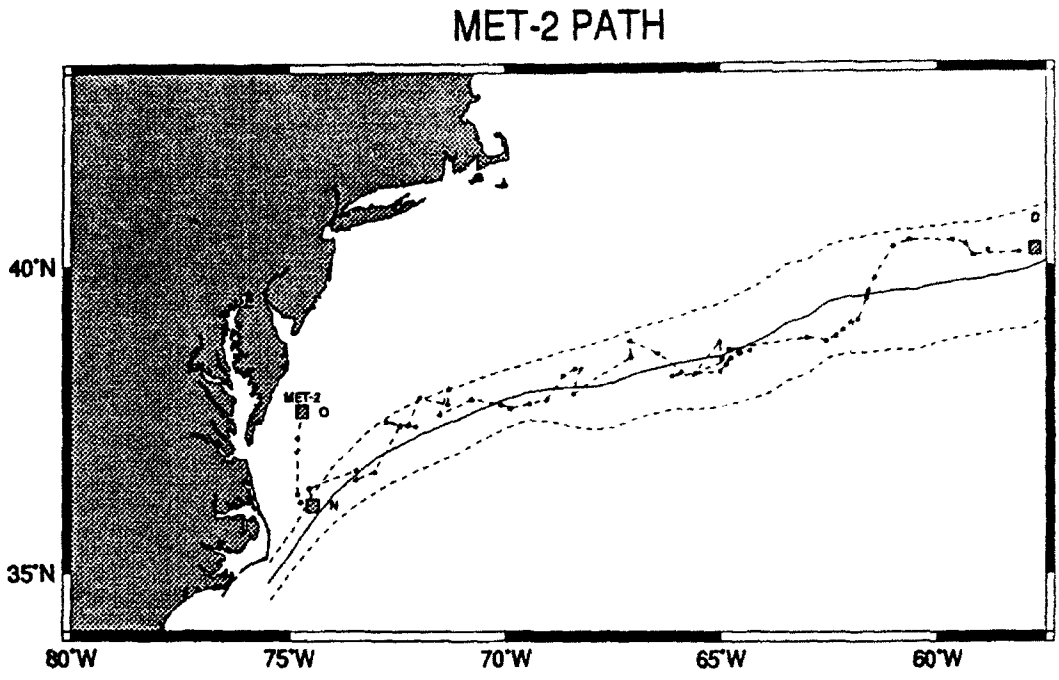

Figure 8: Drift track of MET-2 from September 1990 to December 1990 when contact was lost. (See caption in Figure 7 for meanings of letters).

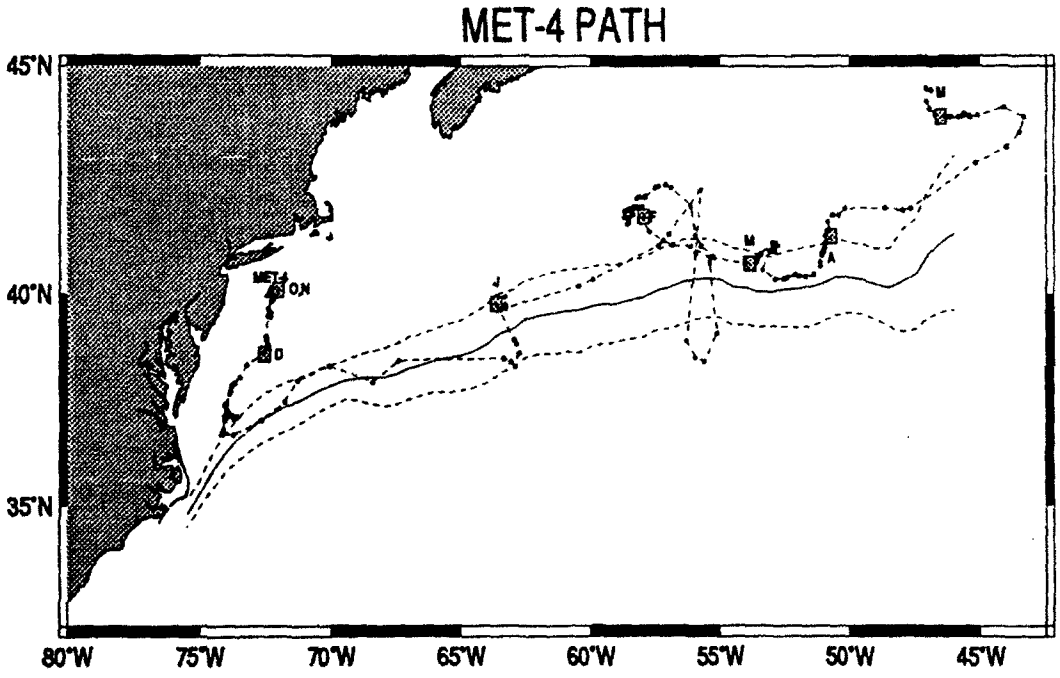

Figure 9: Drift track of MET-4 from September 1990 to May 1991. (See caption in Figure 7 for meanings of letters).

3 Ocean Wave Modeling

Numerical modelling plays a complementary role in achieving the goals of *SWADE*. In particular, the objectives are to examine the usefulness of a wave model as an analysis tool and in general validate wave models with the high quality wave data sets from *SWADE*. Furthermore, a comparison of measured and modelled source physics and the effect of incorporating wave-current interaction will provide additional evidence for refinement of numerical models.

The principal ocean wave prediction model used for these simulations is the third-generation WAM model (WAMDIG, 1989), which computes the directional wave spectrum by integration of the energy transport equation without prior specification of the spectral shape. There are 25 frequency bands from 0.0418 to 0.4114 Hz in logarithmic equally-spaced increments and 24 directional bins at 15-deg intervals. The wind fields are internally interpolated onto the model grids and initially converted to friction velocities using the wind speed dependent drag coefficient described in Wu (1982). The growth and dissipation terms are computed based on a simple coupling of the air-sea dynamics following the wind-wave generation theory of Janssen (1989, 1991). The resulting growth rate depends on both the friction velocity and the roughness length produced by the waves themselves.

Several forecast (Jensen, Graber, and Caruso 1991) and hindcast (Graber, Caruso, and Jensen 1991) studies for the *SWADE* IOPs have been carried out with WAM *Cycles 2, 3, 3.5,* and most recently *4* (Günther, Hasselmann, and Janssen 1991), where the later versions include options for nested grids to specify proper boundary conditions as would arise in situations when swell is propagating into the model domain, and for time and spatially varying currents to study wave-current interactions. More detailed studies are presently under way by the *SWADE* modelling team to investigate (1) sources of errors attributed to wind field specification; (2) differences in source term physics and grid nesting; and (3) the inclusion of depth-dependent wave physics and the influence of wave-current interaction. Model output fields include maps of significant wave height, mean wave period, mean wave direction, swell wave height, swell period and swell direction. In addition, two-dimensional wave spectra are produced at selected output points near buoy stations within the *SWADE* experimental area.

4 Model Domain and Grids

A hierarchy of model grids was designed for *SWADE* to examine the wave physics at different spatial and temporal scales, and the usefulness of a nested system. Each grid is supposed to fulfill a specific function and provide results that can be used to accomplish the goals of the experiment. The WAM model has been implemented in spherical coordinates on three grids described previously (Weller *et al.* 1991):

1. **Basin-scale North and South Atlantic model**
2. **Regional-scale Western North Atlantic model**
3. **Fine Mesh *SWADE* Array model**

Atlantic Basin Model

The basin scale grid covers the entire North and South Atlantic Oceans and extends from 63° S to 72° N and from 100° W to 34° E in 1-deg increments in both latitude and longitude (Figure 10). The primary purpose of this grid is to accurately simulate northward propagating swell originating in the southern ocean and provide boundary conditions for the regional scale model. Also, wave height maps provide some overview of storm activities in both Atlantic basins. The output results will show the quality of the synoptic scale forecast and provide some indication of subscale variability.

Western North Atlantic Model

This medium-resolution grid covers the Western North Atlantic from 24° N to 48° N and from 82° W to 52° W in 0.25-deg increments in both latitude and longitude (Figure 11). The purpose of this model grid is to provide high quality wind and wave analyses for evaluation of *SWADE* scientific objectives and for assessing sources and magnitudes of errors in the wind field specification.

SWADE Model

This high-resolution grid was designed to simulate the small scale wave physics and to improve and verify the source term physics. The grid extends from 35° N to 42° N and from land to 70° W in 0.083-deg increments in both latitude and longitude (Figure 12). The measured meteorology and different interpolation and assimilation schemes will be used to provide winds for these simulations.

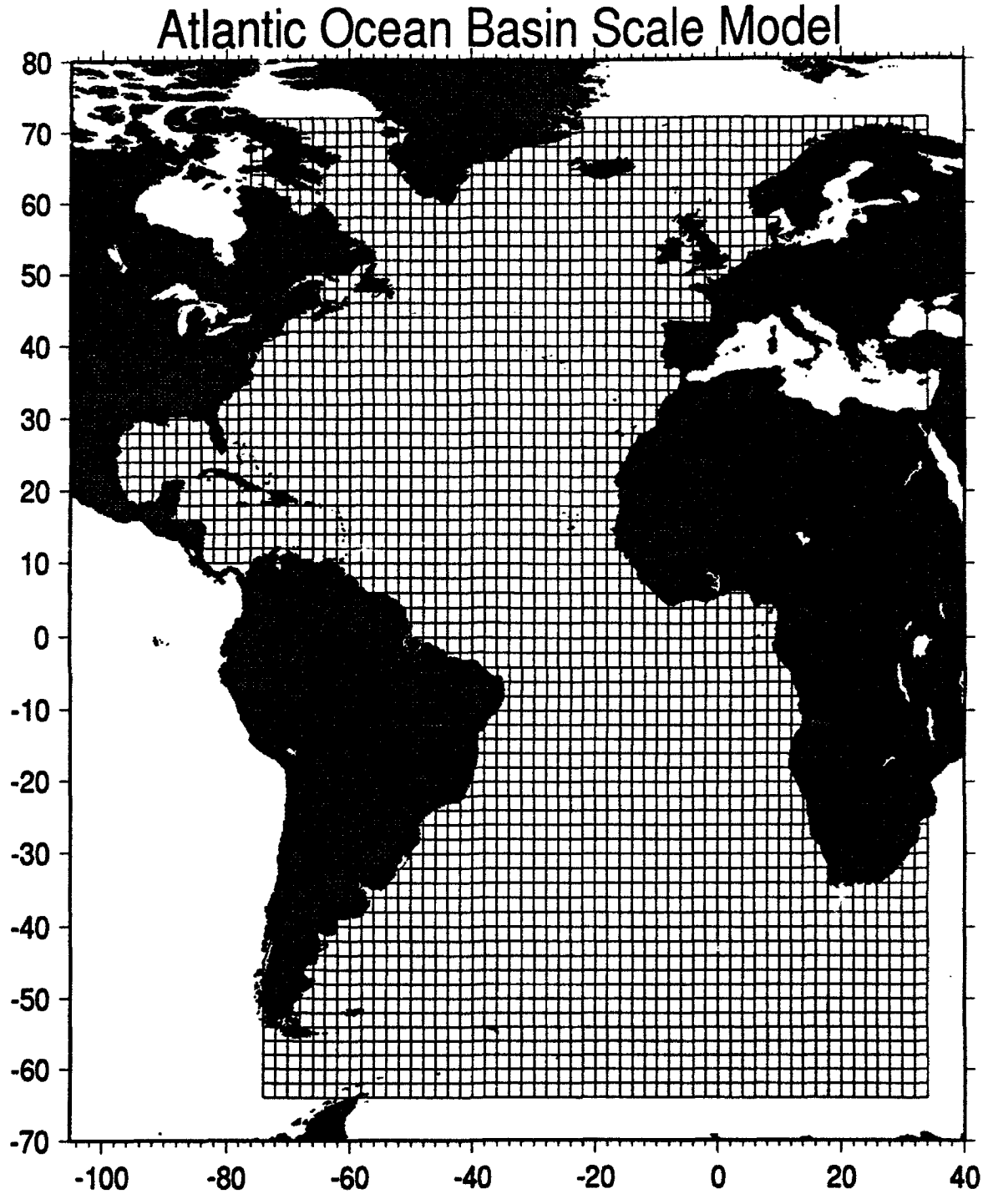

Figure 10: Atlantic Ocean basin-scale model grid.

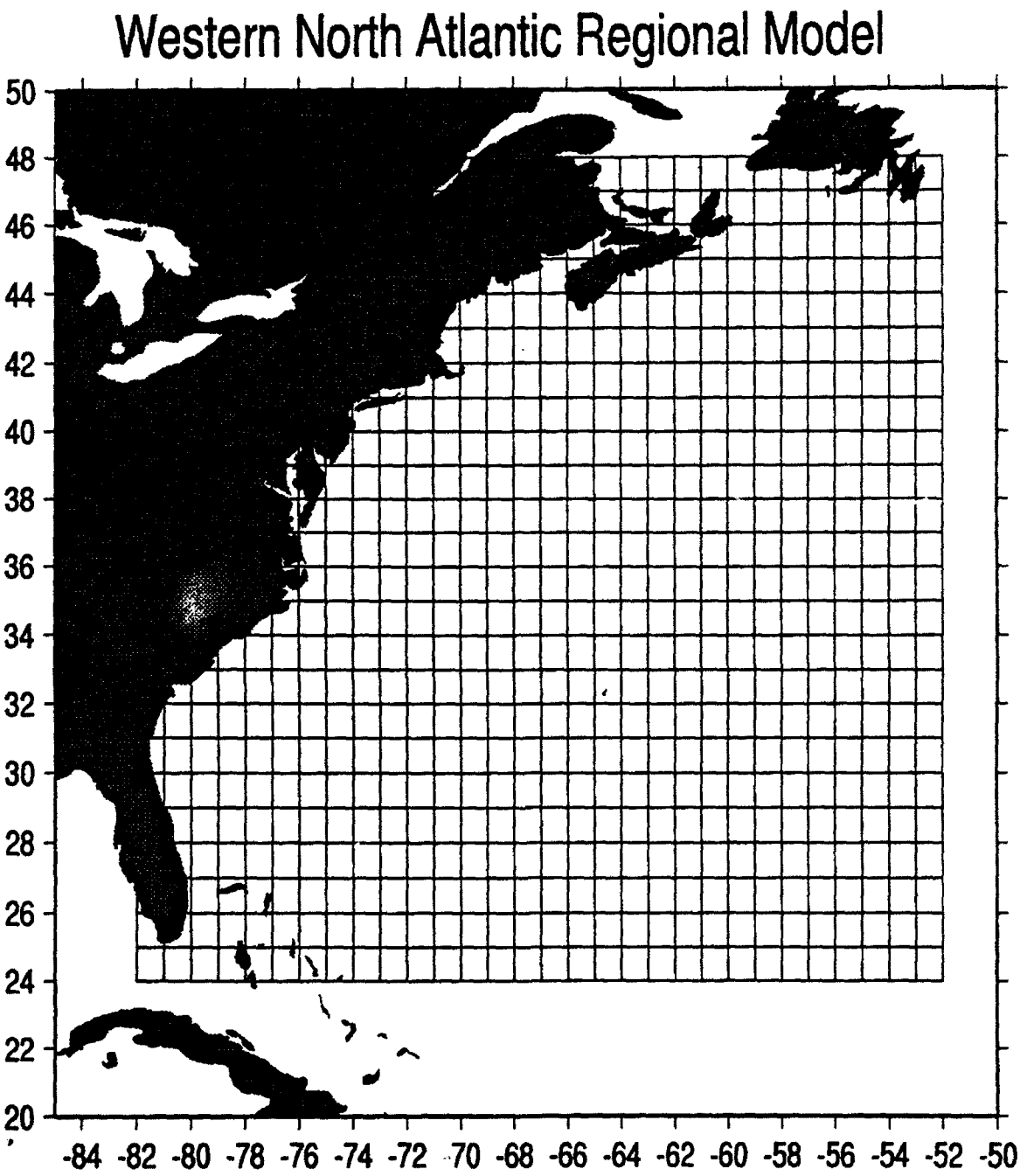

Figure 11: Western North Atlantic regional model grid.

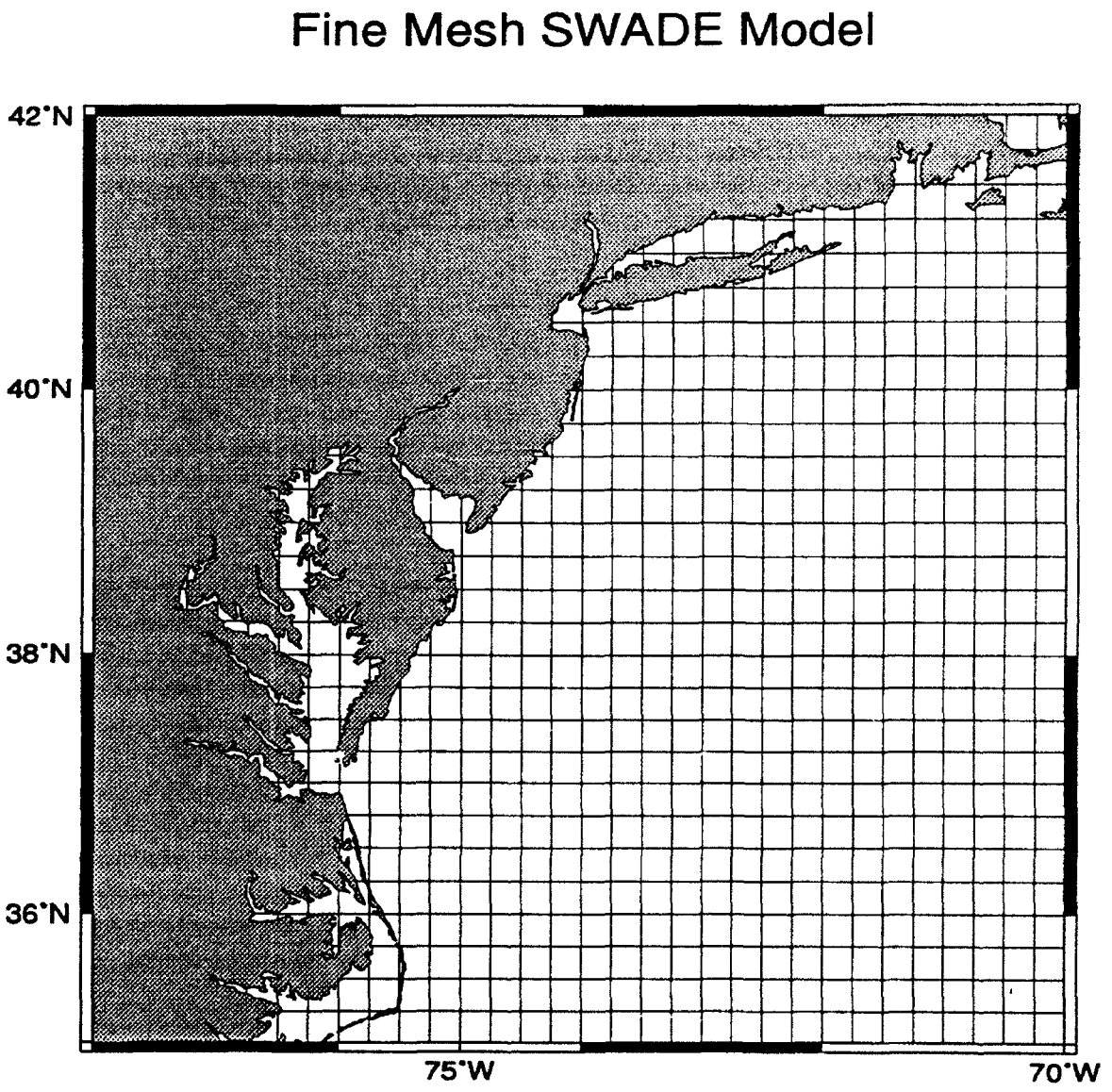

Figure 12: Fine Mesh *SWADE* model grid.

5 Wind Fields

Six different wind field representations are available for this particular time period. Some preliminary results using a subset of these wind fields have been briefly discussed in Graber, Caruso, and Jensen (1991), and they indicate considerable differences in the representations of the atmospheric conditions. The set of wind fields includes analyses from operational numerical weather prediction models such as Fleet Numerical Oceanography Center (FNOC), European Centre for Medium-Range Weather Forecasts (ECMWF), and United Kingdom Meteorological Office (UKMO), objectively interpolating model results from National Meteorological Center (NMC) and NASA/Goddard Space Flight Center (GSFC) and a manual kinematic analysis from Oceanweather/Atmospheric Environment Service (OW/AES). A brief description of each of the wind fields is given below.

Appendix D includes two maps per day of wind vectors and the corresponding contours of significant wave height for the OW/AES model simulations on the regional grid for the entire IOP-1. For the time period from 24 October 1990, 12:00 GMT to 28 October 1990, 12:00 GMT the wind vector fields and corresponding wave hindcasts from the other wind field models are also presented. Note that the frequency of maps is every 3 hr from 26-28 October, which covers the major storm period.

FNOC

The FNOC has provided analyzed and forecast wind stress and 19.5-m neutrally stable wind fields derived from the Navy Operational Global Atmospheric Prediction System (NOGAPS) spectral forecast model (Hogan and Rosmond 1991). The predicted winds are computed with the (T80) model system, which uses 80 Fourier coefficients and 18 vertical layers from the surface to a pressure level at 10 mb. The fields are spectrally interpolated in the horizontal to 1.5 deg. The NOGAPS uses a planetary boundary-layer (PBL) model similar to that of the ECMWF (Louis, Tiedtke, and Geleyn 1982), but with a major modification for the computation of surface fluxes when the PBL is conditionally unstable. The 19.5-m neutrally stable winds are directly computed from the wind stress fields at each local grid point taking into account atmospheric stability effects. A final, linear interpolation is done onto a spherical grid with a spatial resolution of 1.25 deg in latitude and longitude. The time interval of wind and wind stress fields is every 6 hr starting at 00:00.

ECMWF

Analyzed 10-m wind fields from the ECMWF generated by their operational atmospheric general circulation model are available for the entire *SWADE* period. These analyzed winds are from the ECMWF/TOGA (Tropical Ocean-Global Atmosphere) advanced operational analysis surface and diagnostic fields data set. The geometrical coverage is specified on a (N80) Gaussian grid with a spatial resolution of 1.125 deg in latitude and longitude. The time interval of wind fields is every 6 hr beginning at 00:00. Analyzed surface pressure fields and surface temperature fields are also available with the same spatial and temporal

resolution.

NMC/GSFC

Two additional wind field products are available from the NMC and NASA/GSFC. Both wind fields were derived from the first guess fields of NMC's coarse (2.5° × 2.5°) large-scale analysis. In each case the observed data are reinserted into a high-resolution grid where grid points with data remain unaltered, whereas non-data points are computed using a "conditional" relaxation procedure.

The NMC model winds are generated with an *objective interpolation* scheme which corrects the nearest grid point according to the data value and relaxes all non-data points. The method includes a check on gross errors. The fidelity of the wind field is determined by withholding one piece of ship data at a time. This is repeated about 10 times. The resulting wind fields are regridded covering the regional model domain with a resolution of 0.3 deg in latitude and 0.5 deg in longitude. The time interval between wind fields is 6 hr.

The GSFC model winds are determined with the *successive correction method* which uses seven sweeps over the model domain and successively reduces the area of influence in each pass from 500 km to 120 km. Consistency checks and error minimization are only performed at buoy locations. No additional quality checks are made by withholding individual buoy measurements. The final output is a spatially high-resolution wind field on a 0.25- by 0.25-deg grid. The time interval between successive wind fields is every 3 hr.

Both methods make a final check of the wind fields for consistency and the goodness of these winds is evaluated with root mean square error statistics.

OW/AES

High-resolution wind fields were developed by OW/AES over a limited domain, coinciding approximately with the fine-mesh *SWADE* grid. These wind fields were produced with a manual kinematic analysis, originally described in Cardone et al. (1980), from pressure fields, air and sea surface temperature fields, ship and buoy data. All data are carefully screened for inconsistencies and measured winds are adjusted in height and corrected with a stability-dependent surface layer model to effective neutral 20-m height hourly averages. Hourly averages of wind speed and direction are computed from three consecutive hourly buoy observations with weights of 0.25, 0.5 and 0.25, respectively. The detailed hand analysis of the pressure and temperature fields carefully preserves temporal and spatial continuity of low pressure centers and frontal boundaries. Outside of the limited domain, the effective neutral winds are calculated with the marine boundary layer model of Cardone (1969). Time histories of measured and modelled and standard statistical measures of difference are used to evaluate the quality of the final wind fields.

The resulting high-resolution winds are gridded onto a 0.5- by 0.5-deg grid over the regional model domain and are available hourly to simulate accurately the temporal evolution

of the storm centers and frontal systems passing over the *SWADE* domain.

UKMO

These wind fields are computed from the coarse-mesh, 11-layer general atmospheric circulation model in operational use at the UKMO (Bell and Dickinson 1986). Global coverage is implemented on a mesh with grid lengths of 1.5-deg in latitude and 1.875-deg in longitude. A 6-hr data assimilation cycle is employed, and physical and subgrid-scale processes are also included in the model (Gilchrist and White 1982). Analyzed winds at the 19.5-m height are available every 2 hr beginning at 00:00.

Winds from the limited-area fine-mesh model are also available at hourly intervals. While the resolution of the fine-mesh model is twice that of the coarse mesh model (*i.e.*, $\Delta\phi = 0.75 - deg$ and $\Delta\lambda = 0.9375 - deg$), its North Atlantic coverage extends only as far south as 30° N, which is not sufficient for the Western North Atlantic regional model grid domain.

6 Surface Currents

A special data set of surface currents was generated from the quasi-geostrophic Harvard open ocean model (Robinson and Walstad 1987). The currents were generated using the Harvard GULFCAST "feature model" for the Gulf Stream with embedded rings from the nowcast locations (Glenn, Porter, and Robinson 1991). Input data of the location of the Gulf Stream North Wall and warm and cold core rings were provided by the Naval Oceanographic Office. Daily maps of surface velocity fields consisting of nowcast and forecast fields are available from October 20 to 31, 1990. The spatial resolution of the current vectors is 15 km. The average accuracy of the Gulf Stream position within the GULFCAST model domain is estimated to be about ±30 km based on the assumption that the input data from digital infrared imagery, AVHRR, and GEOSAT altimetry is accurate to about ±15 km and the Oceanographic Analysis Charts to within ±30 km (Glenn, Porter, and Robinson 1991).

The cartesian grid of the GULFCAST model is projected onto an f-plane at $\phi_o = 38.4°$ N and $\lambda_o = 61.4°$ W. The grid domain is rotated by $\theta = 22°$ counterclockwise from east and is approximately parallel to the coastline between Cape Hatteras and Nova Scotia, but covers only the northern model domain of the Western North Atlantic grid. The relationship between a point (X, Y) in a cartesian coordinate system with principal axes along east-west and north-south directions and a point (x, y) in the GULFCAST model domain is given by

$$\begin{aligned} X &= x\cos\theta - y\sin\theta \\ Y &= x\sin\theta + y\cos\theta \end{aligned}$$

The equivalent longitude and latitude specification of a point (X, Y) in a spherical earth coordinate system is determined by

$$\begin{aligned} \lambda &= \lambda_o - \frac{X}{a\cos\phi_o} \\ \phi &= \phi_o + \frac{Y}{a} \end{aligned}$$

where a = 111.12 km.

Daily maps of the surface currents within the fine-mesh *SWADE* model grid for IOP-1 are shown in Appendix E from 20 October 1990, 00:00 GMT to 31 October 1990, 00:00 GMT.

7 The SWADE Storm

The original IOP-1 or "shake-down" period took place from November 5 to 9, 1990. During this time the weather was uncooperative in the sense of being uneventful for winds and waves, most aircraft were not available and several other measurement components were still being prepared or serviced due to an intense extra-tropical storm which swept over the *SWADE* experimental region on October 26. Therefore, the steering committee of *SWADE* decided to designate the time period from October 20 - 31, which included the now famous *SWADE Storm*, as IOP-1. The following paragraphs will briefly describe the meteorological and oceanic conditions leading up to, during, and after the *SWADE Storm*. An overview is given of the measurements collected during this storm period and some results are presented from the wind and wave model simulations for this severe event.

During IOP-1, three separate storm systems passed in rapid succession over the *SWADE* array, causing significant damage along the Atlantic seaboard and reaching hurricane force gusts from Cape Hatteras to Cape Cod. The middle storm turned out to be the most severe one of them all.

On October 24 a newly formed surface low over coastal North Carolina became quickly energized from the unseasonally warm waters of the Gulf Stream and deepened at a much faster rate than predicted. This led to very steep pressure gradients along the North Carolina and Virginia coasts due to a number of small-scale cyclonic centers that formed an elongated shear zone extending all the way up to the Canadian maritime coast. This elongated structure resulted in a greatly "linearized" fetch and led to higher than expected winds in this region. As the storm proceeded in an east-northeastward direction, it reached a minimum pressure of 984 mb on October 26 just over the *SWADE* region. Figure 13 shows the surface analysis chart at the height of the storm. The very intense and tight circulation more commonly found in tropical cyclones was clearly evident in the drastic changes of atmospheric pressures observed by the *SWADE* buoys. Pressure drops of 12 mb within 6 hr and subsequent pressure rises of nearly 25 mb are often features of hurricanes. The storm proceeded along an east-northeast track and after occlusion (a warm front is overtaken by a cold front) the storm accelerated towards the open sea. Figure 14 shows the storm track over a 24-hr period for October 26.

Sea states associated with this storm were in excess of 5 m almost everywhere along the seaboard between Cape Hatteras and Cape Cod. Some buoys further offshore such as 41001 and 44015 recorded significant wave heights up to 9 and 8 m, respectively. It is very probable that individual waves attained heights twice the observed significant height values. It was also during this storm that the Spar buoy was sunk. According to the captain of the tanker M/S *Tropic Sun*, which passed by the Spar around 1600 EDT inbound to Delaware Bay, the buoy was floating upright and with all its sensors intact. This was approximately 4 hr after the peak of the storm as observed by the nearby buoy 44015. ARGOS transmission stopped around 2000 EDT (Dr. Charles Flagg, Brookhaven National Laboratory, 1992, personal communication). The Spar was located on the bottom by the R/V *Oceanus* on October 30. Data from an acoustic survey determined that the resting place of the Spar was

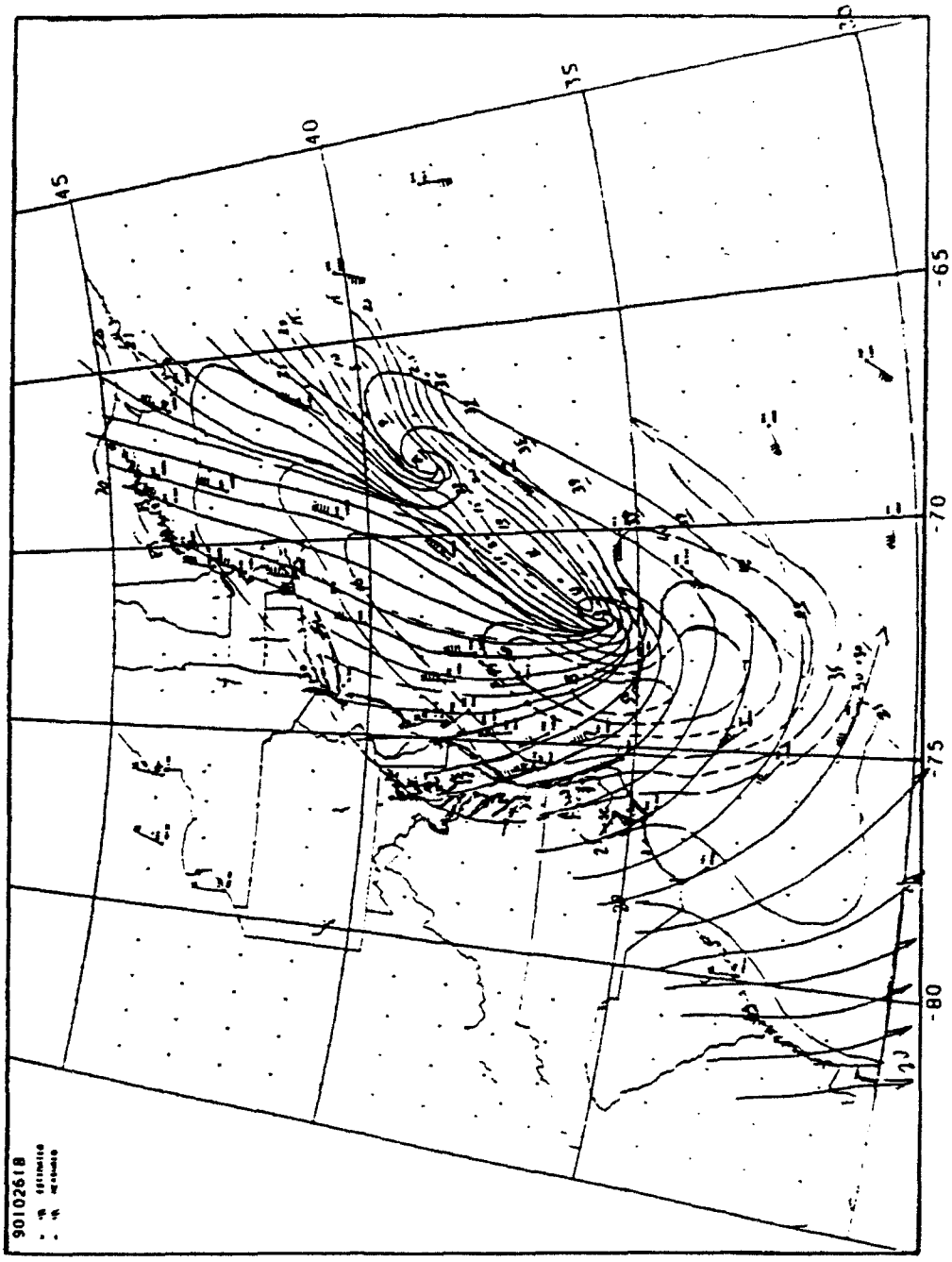

Figure 13: Surface analysis of 26 October 1990 at 18:00 UTC (from Cardone et al. (1993)).

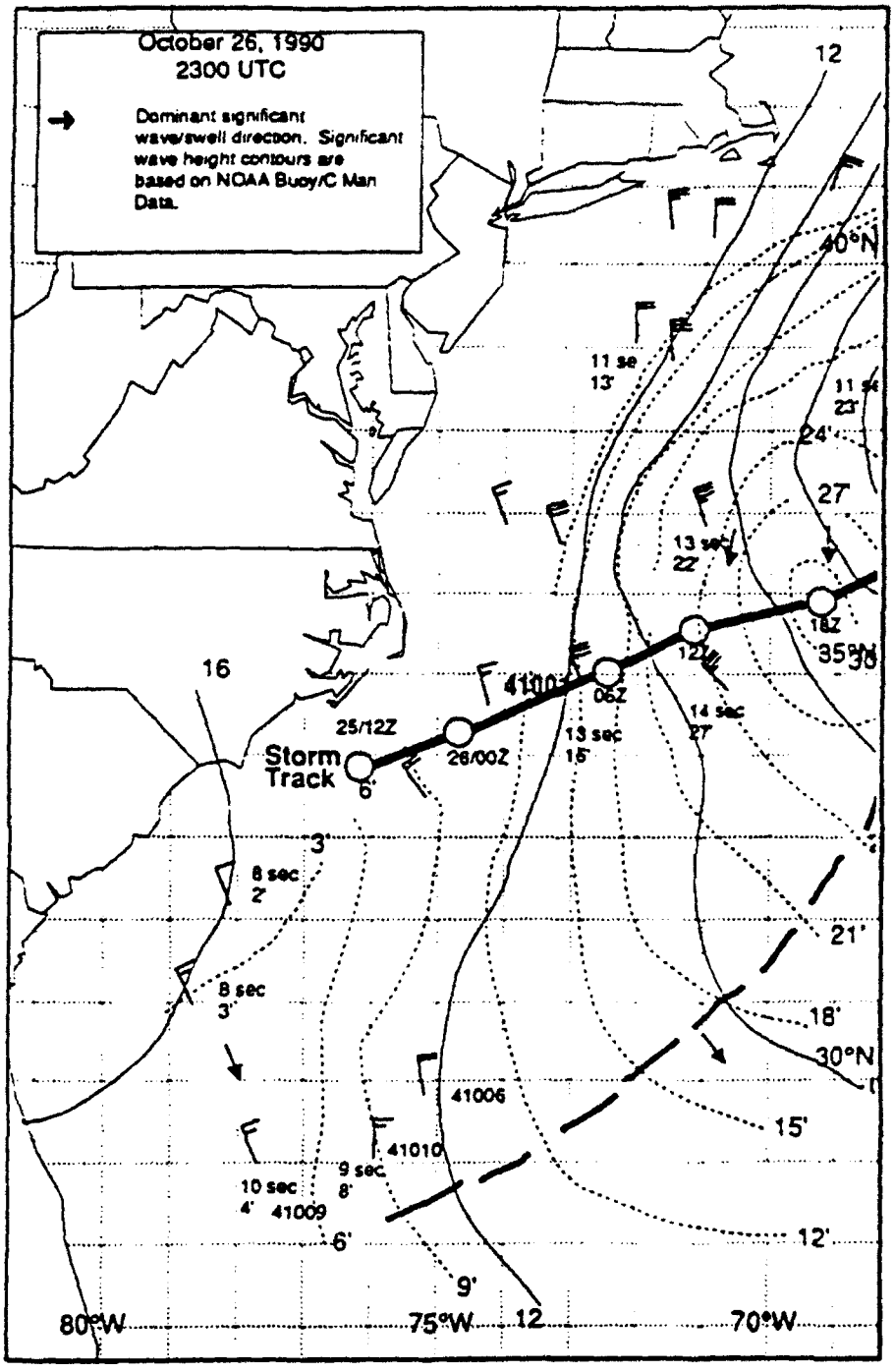

Figure 14: Storm track of central pressure position of "*SWADE Storm* " (from Morris (1991)).

in waters 301.9-m deep at 37° 28.4' N, 74° 22.6' W. This location is about 3 km southwest of the original deployment position, which was in 200-m water depth (Graber and Boutin 1991). In mid-June 1992 the USNS *GRASP* recovered the Spar and evaluations are under way to determine the cause of its failure.

8 Summary

This report provides a summary of wind, wave and meteorological measurements during the first intensive observation period (IOP-1) of the *SWADE*. The time series of wind, wave and meteorological parameters provide a guide to the availability of various observations during IOP-1 and a first look at the temporal and spatial variability of the dynamics during this extreme storm event. The hindcast results from the third-generation ocean wave model (WAM) with six different wind fields is intended to show the diverse representation of this storm event as well as a description of the larger scale meteorological and sea state conditions during IOP-1.

Two subsequent reports will describe the general observations of the meteorological and oceanographic conditions for IOP-2 and IOP-3.

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Appendix A: Time Series from SWADE and NDBC Buoys

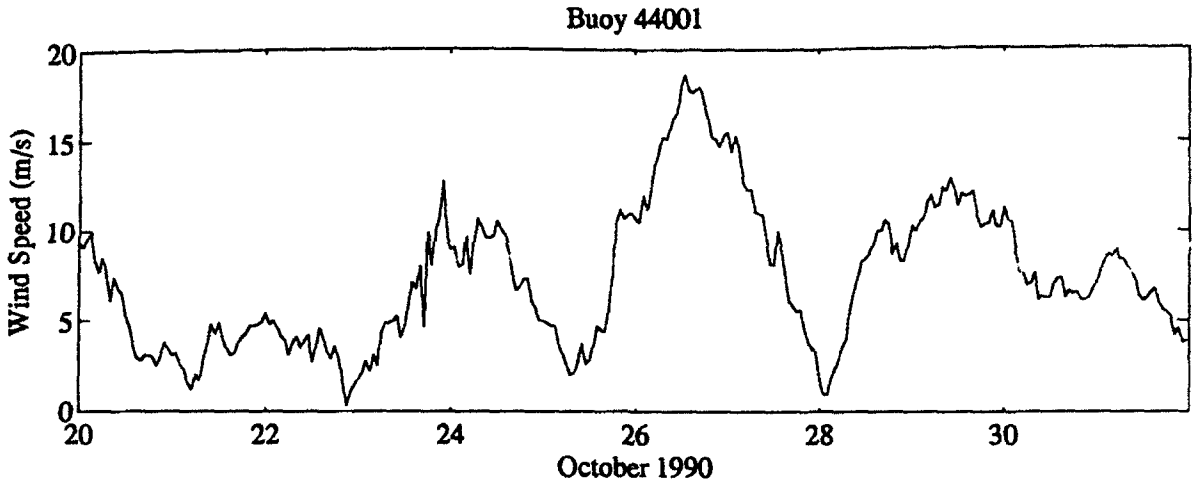
Time series plots of the observed data are presented in this appendix in the following sequence:

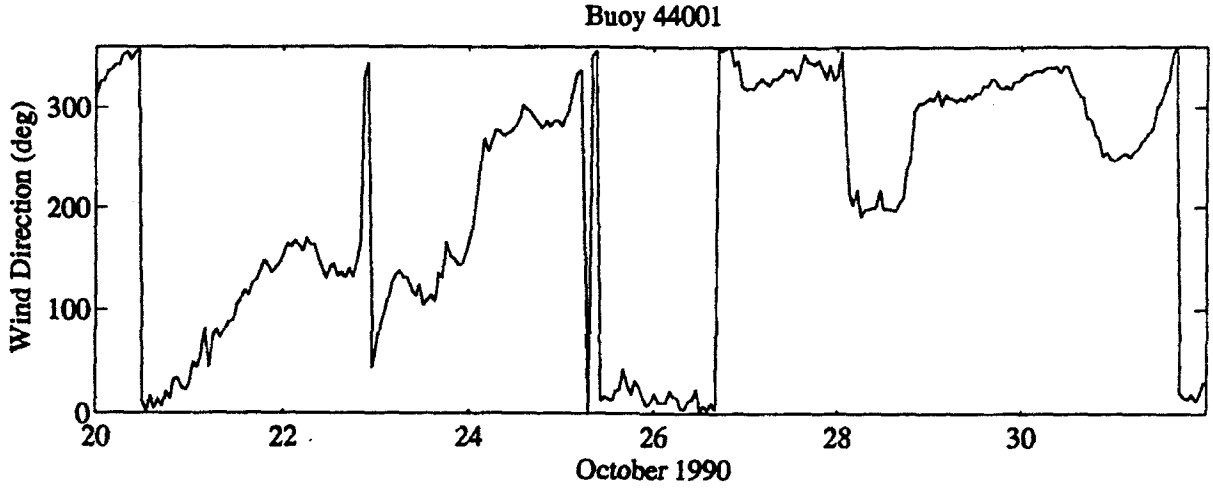
1. **Directional Wave Buoys**

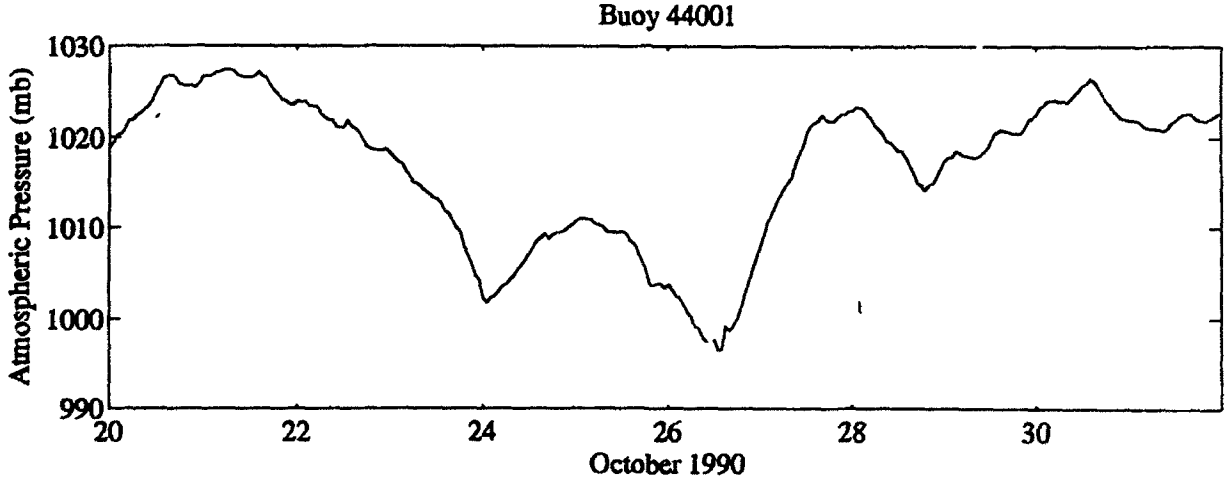
   - Discus Buoy "North" (44001)
   - Discus Buoy "East" (44015)
   - Discus Buoy "CERC" (44014)

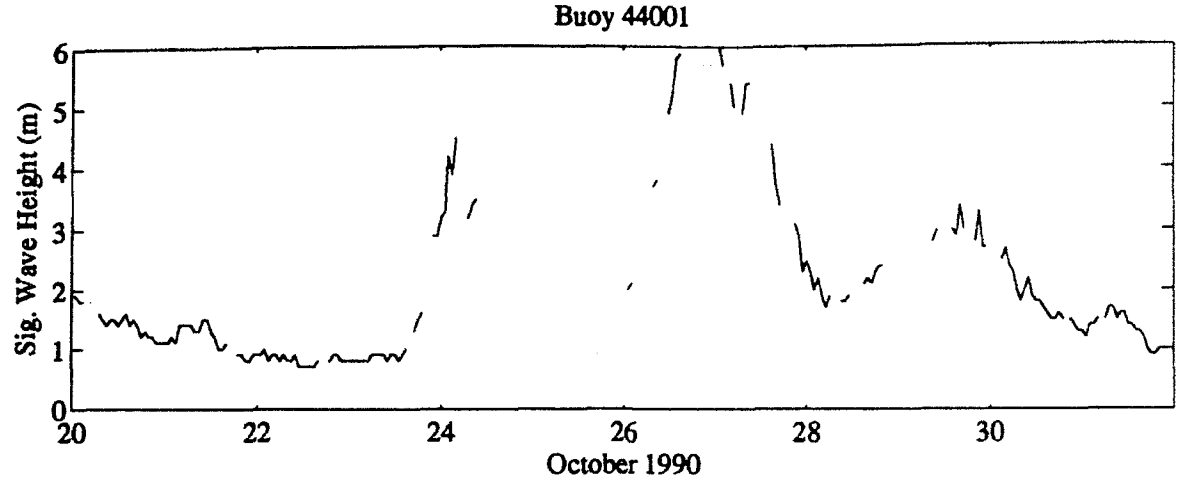
2. **Non-directional Buoys and C-MAN Stations**

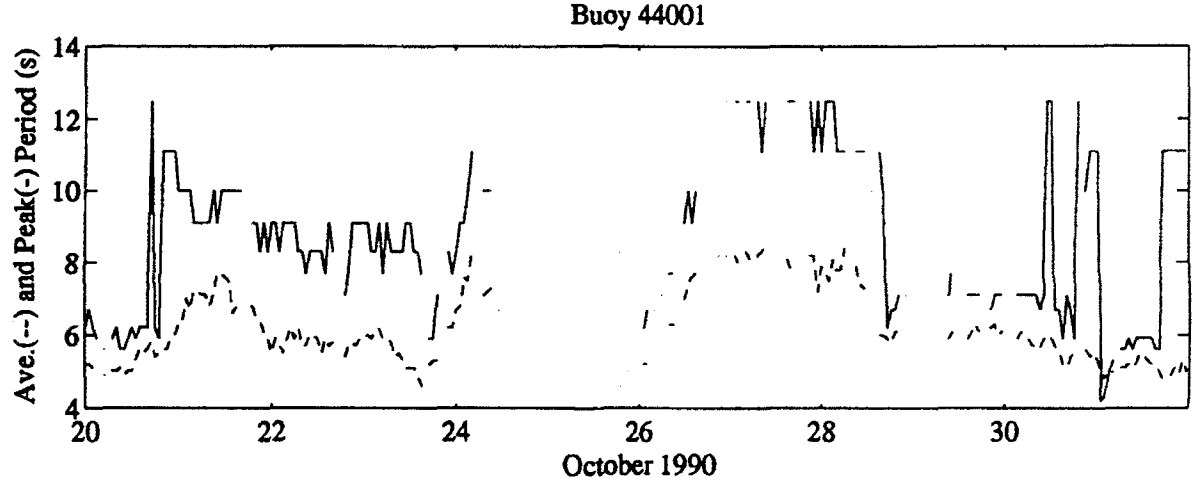
   - Buoy 41001
   - Buoy 44004
   - Buoy 44008
   - Buoy 44009
   - Buoy 44011
   - Buoy 44012
   - C-MAN Station DSLN7
   - C-MAN Station CHLV2
   - C-MAN Station BUZM3

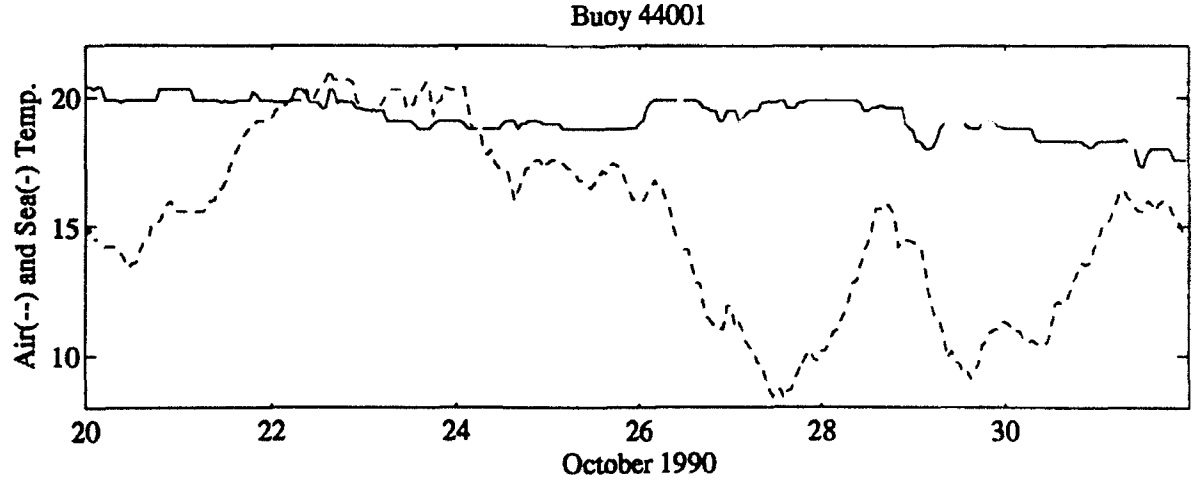

Buoy 44001
Wind Speed (m/s)
0
5
10
15
20
20
22
24
26
28
30
October 1990

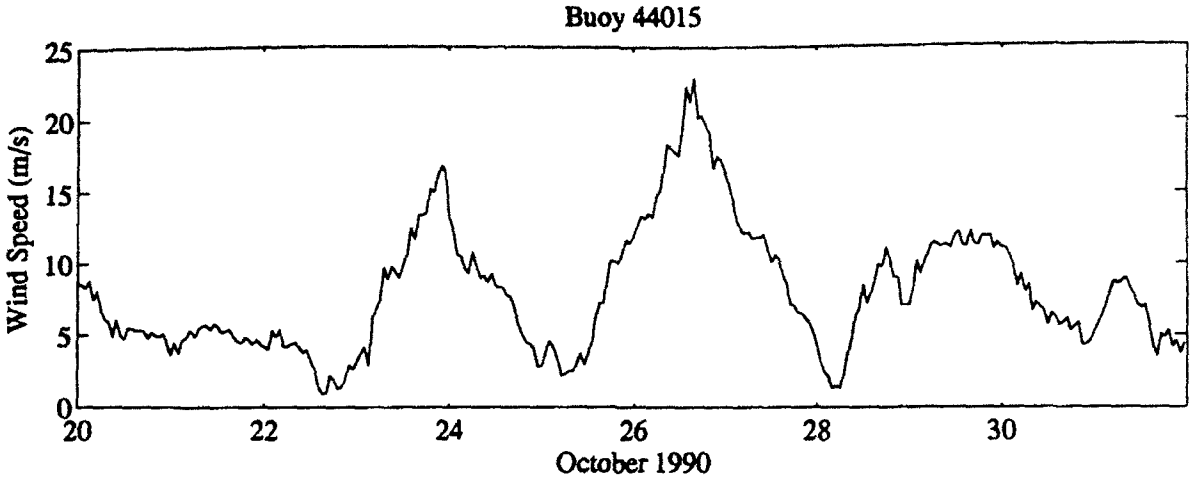

Buoy 44001
Wind Direction (deg)
0
100
200
300
20
22
24
26
28
30
October 1990

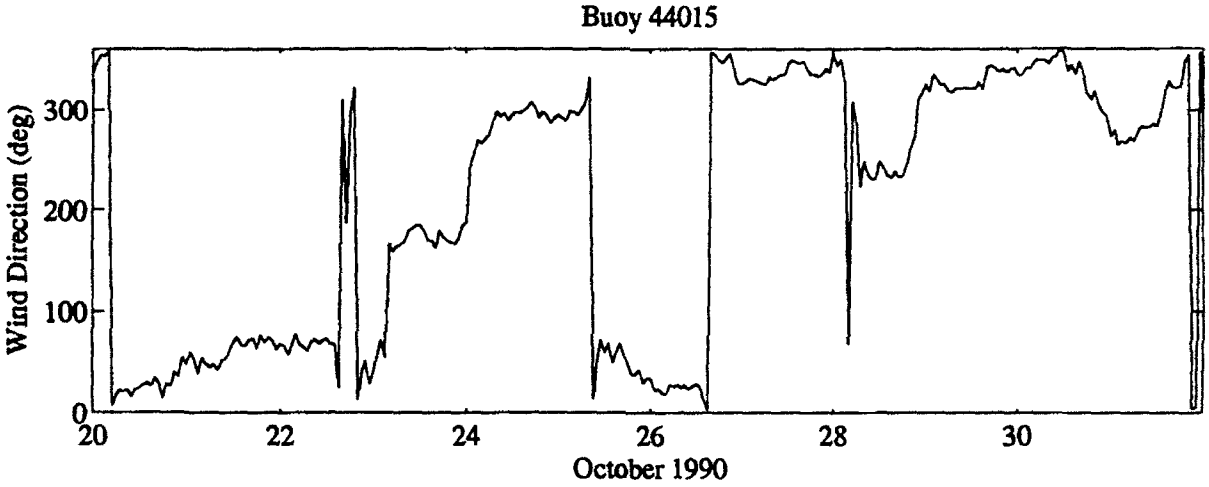

Buoy 44001
Atmospheric Pressure (mb)
990
1000
1010
1020
1030
20
22
24
26
28
30
October 1990

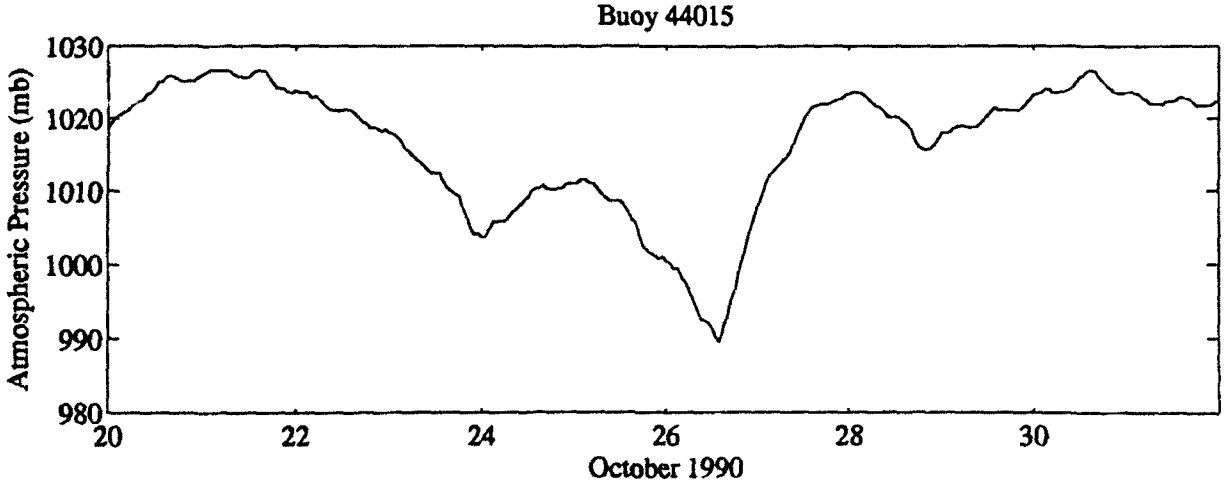

Buoy 44001
Sig. Wave Height (m)
0
1
2
3
4
5
6
20
22
24
26
28
30
October 1990

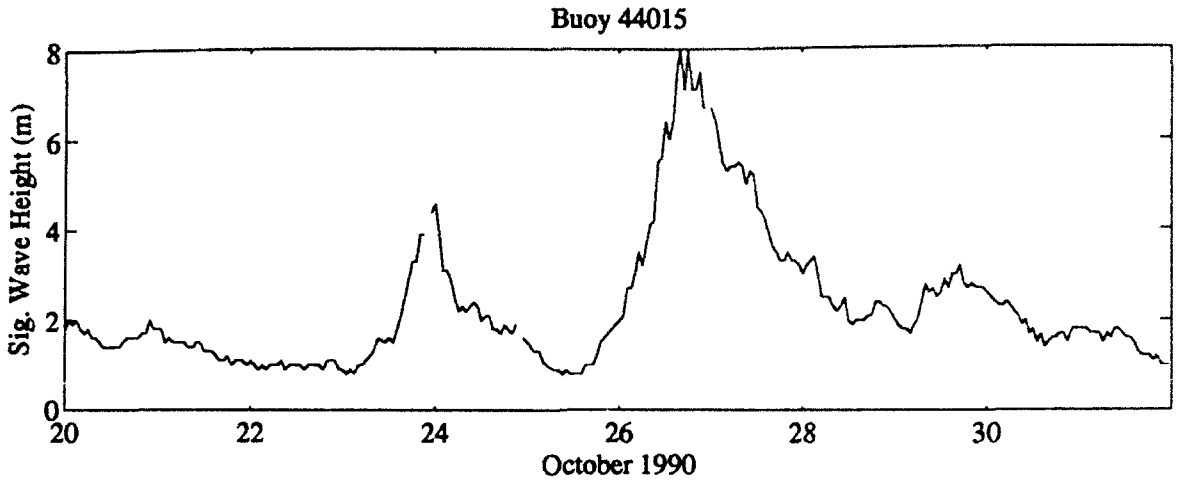

Buoy 44001
Ave.(--) and Peak(-) Period (s)
4
6
8
10
12
14
20
22
24
26
28
30
October 1990

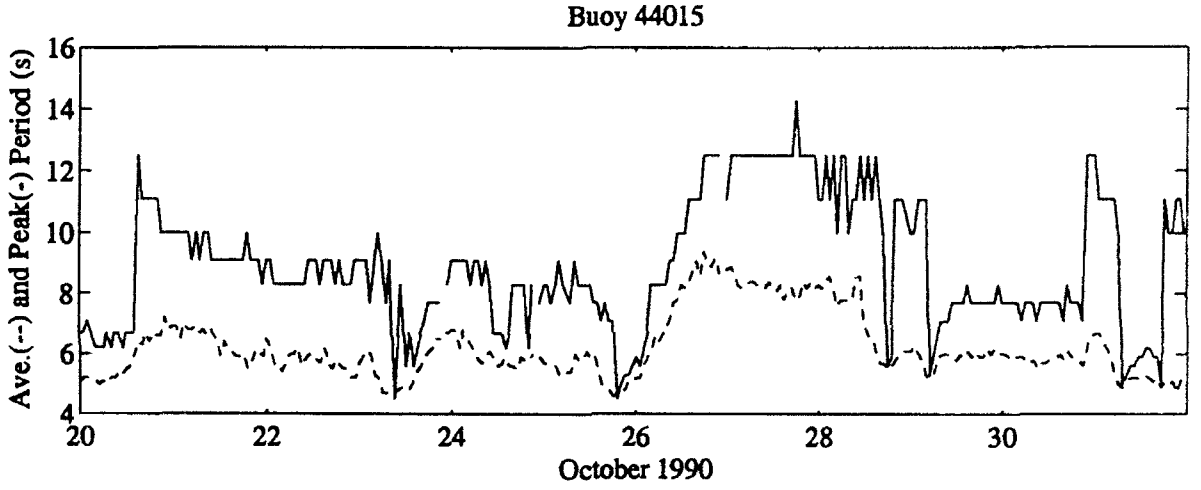

Buoy 44001
Air(--) and Sea(-) Temp.
10
15
20
20
22
24
26
28
30
October 1990

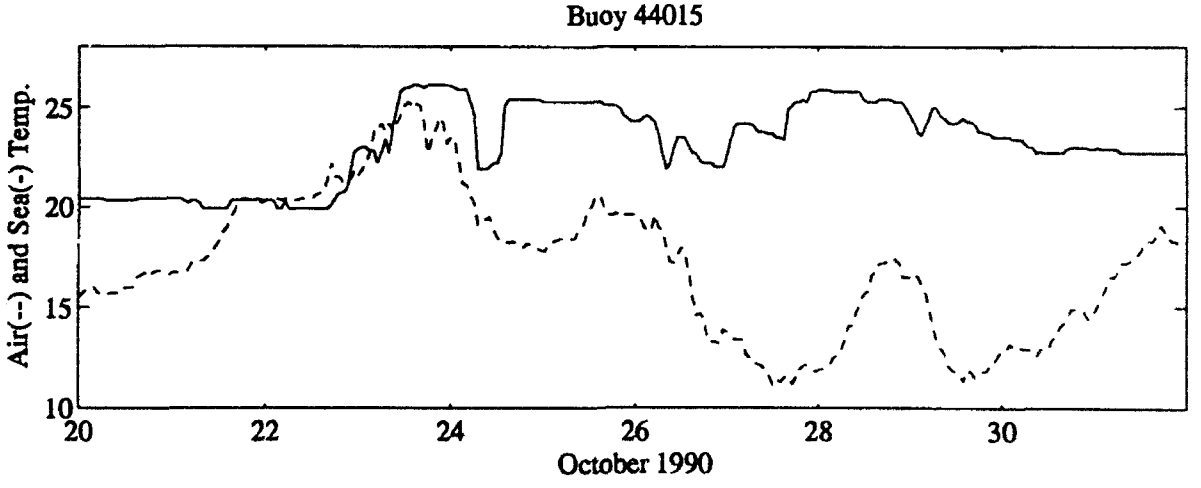

Buoy 44015
Wind Speed (m/s)
25
20
15
10
5
0
20
22
24
26
28
30
October 1990

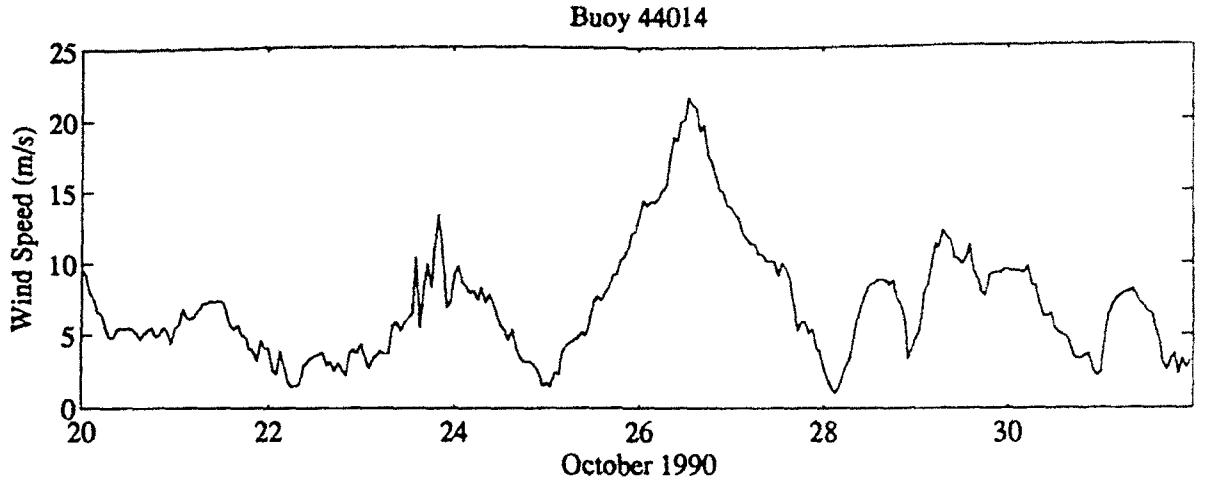

Buoy 44015
Wind Direction (deg)
300
200
100
0
20
22
24
26
28
30
October 1990

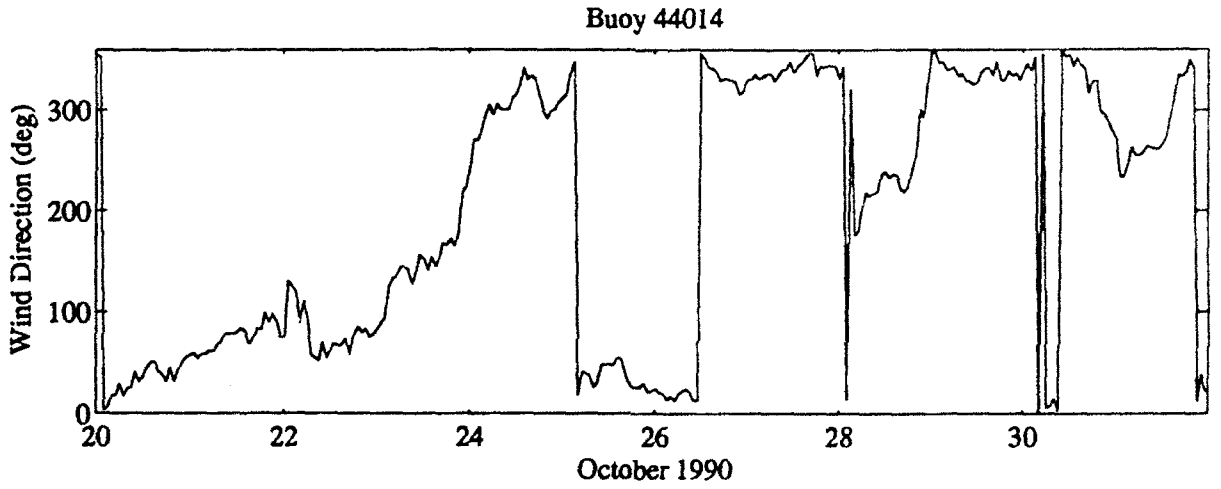

Buoy 44015
Atmospheric Pressure (mb)
1030
1020
1010
1000
990
980
20
22
24
26
28
30
October 1990

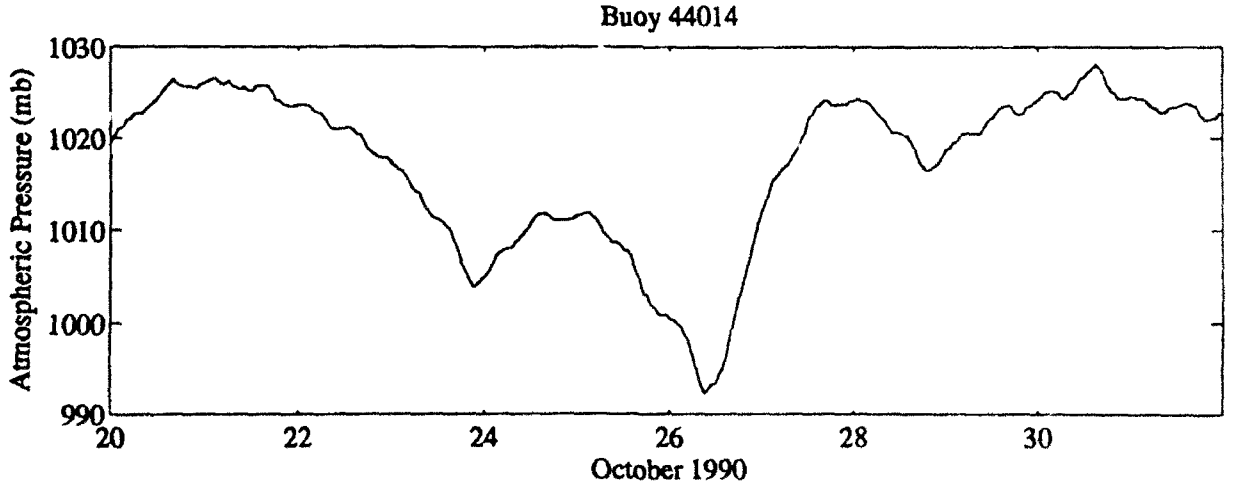

Buoy 44015
Sig. Wave Height (m)
0
2
4
6
8
20
22
24
26
28
30
October 1990

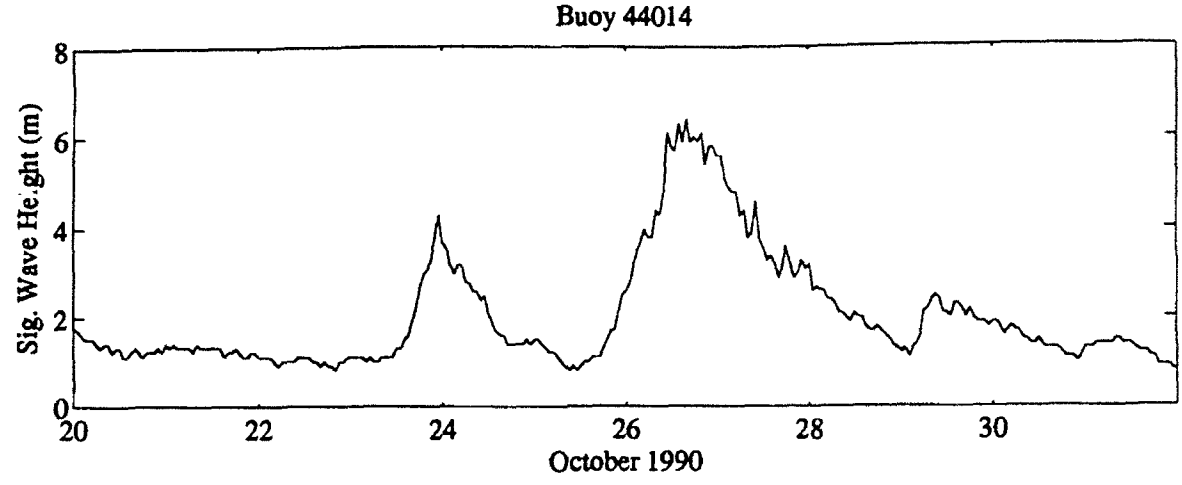

Buoy 44015
Ave.(--) and Peak(-) Period (s)
4
6
8
10
12
14
16
20
22
24
26
28
30
October 1990

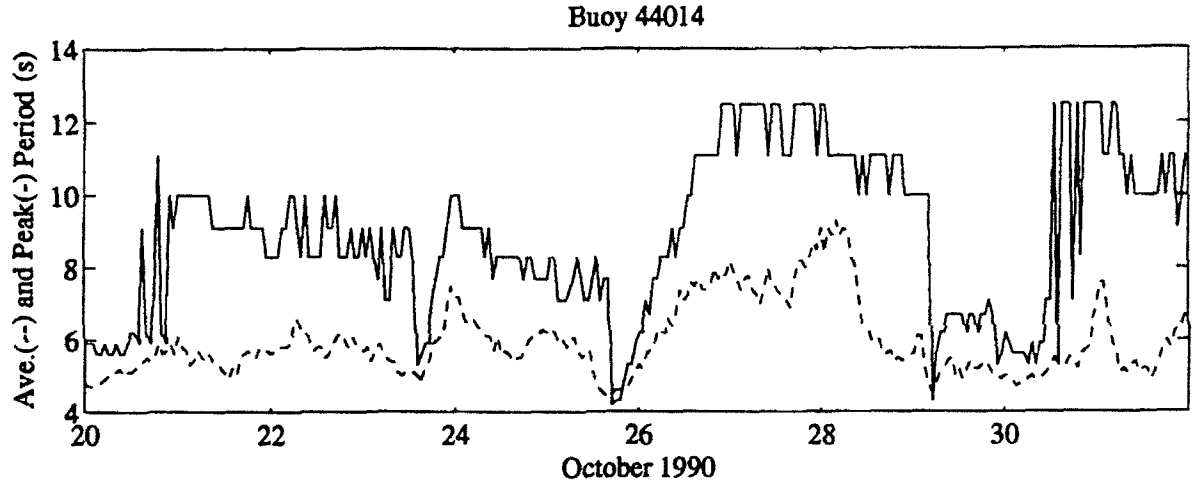

Buoy 44015
Air(--) and Sea(-) Temp.
10
15
20
25
20
22
24
26
28
30
October 1990

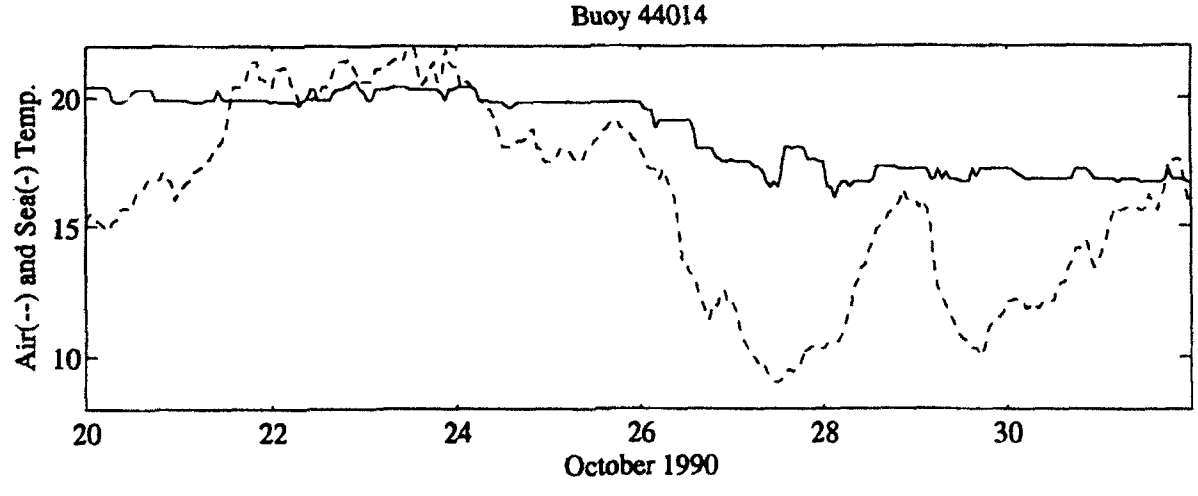

Buoy 44014
Wind Speed (m/s)
25
20
15
10
5
0
20
22
24
26
28
30
October 1990

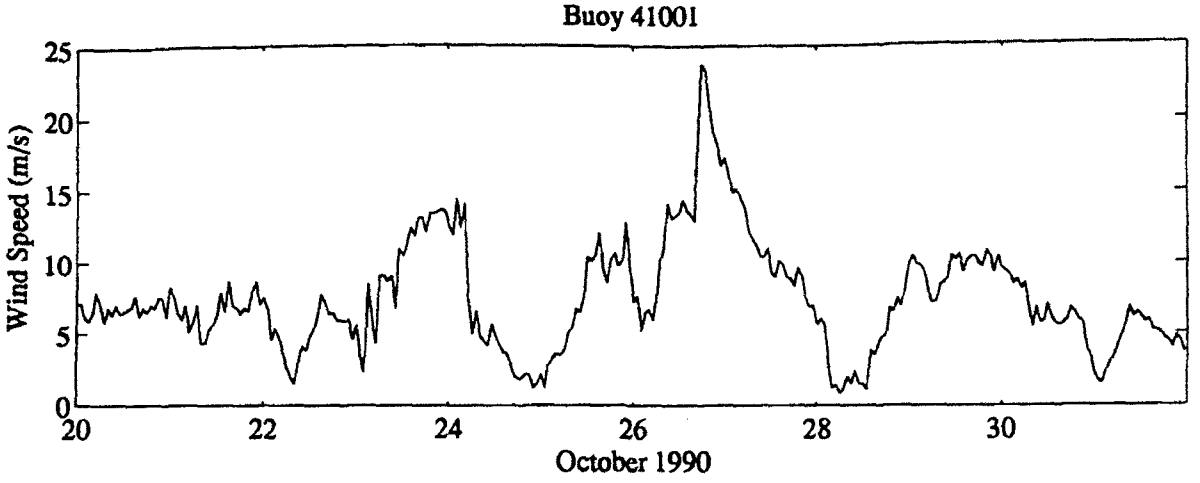

Buoy 44014
Wind Direction (deg)
300
200
100
0
20
22
24
26
28
30
October 1990

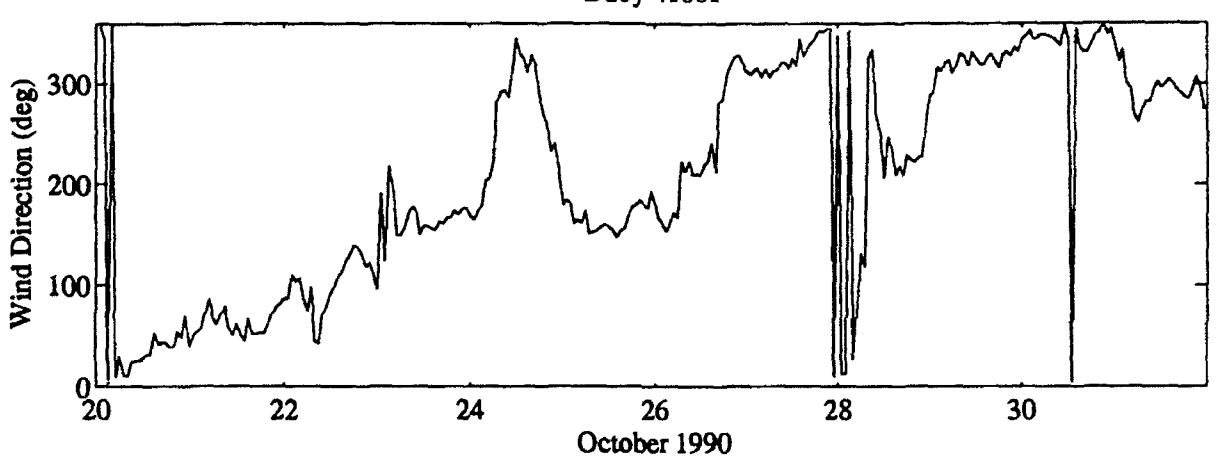

Buoy 44014
Atmospheric Pressure (mb)
1030
1020
1010
1000
990
20
22
24
26
28
30
October 1990

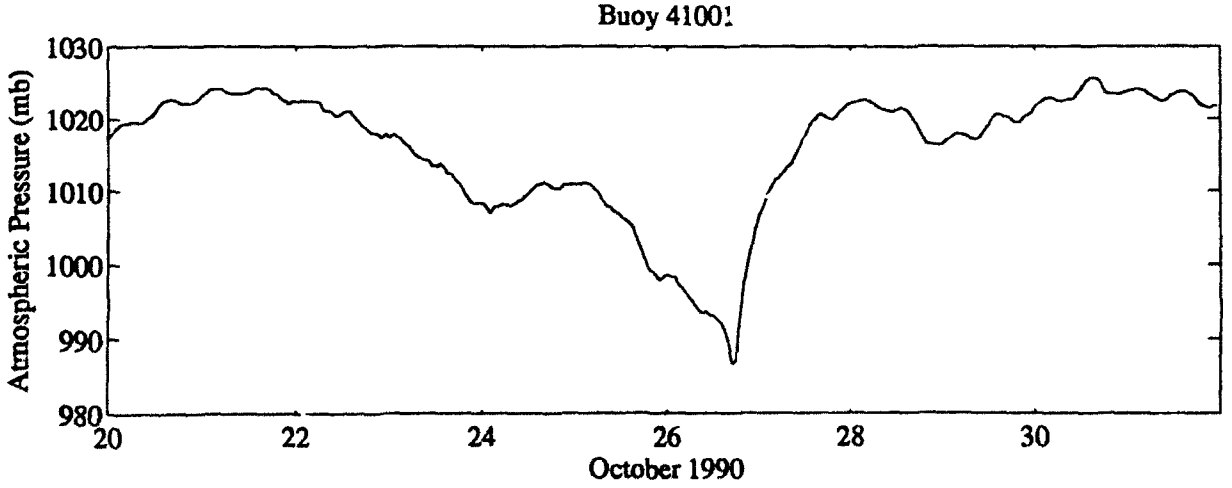

Buoy 44014
Sig. Wave He.ght (m)
0
2
4
6
8
20
22
24
26
28
30
October 1990

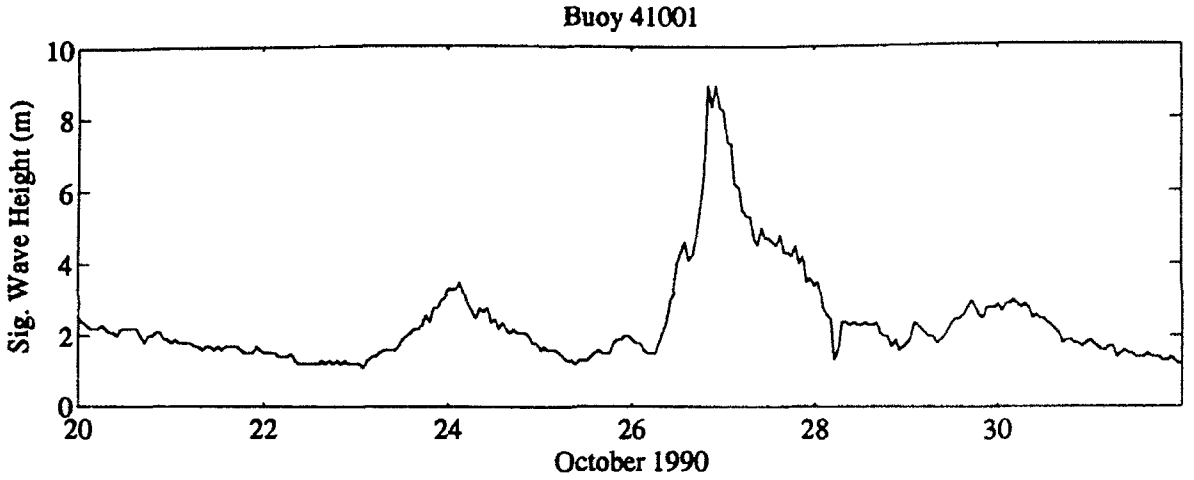

Buoy 44014
Ave.(--) and Peak(-) Period (s)
4
6
8
10
12
14
20
22
24
26
28
30
October 1990

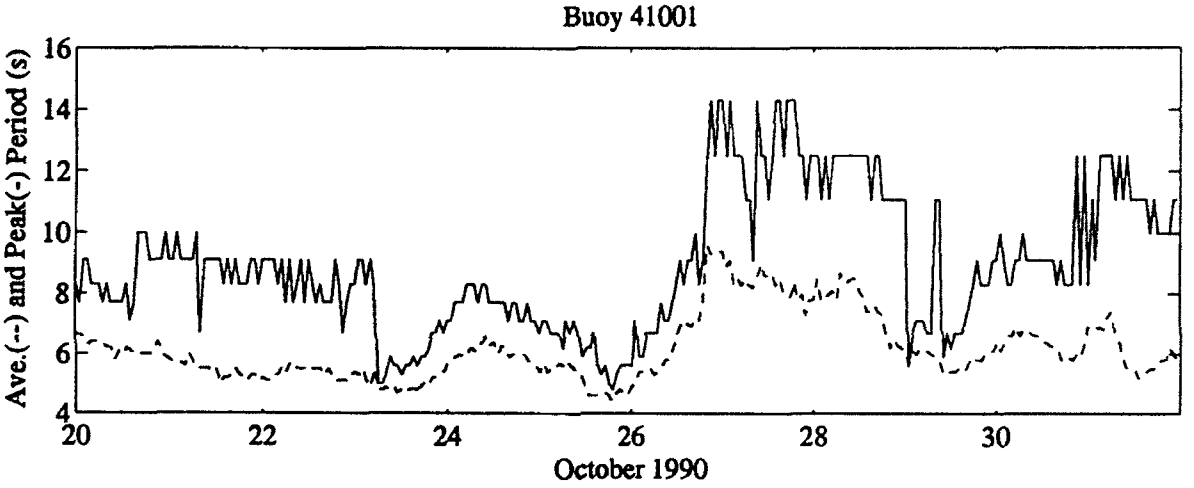

Buoy 44014
Air(--) and Sea(-) Temp.
10
15
20
20
22
24
26
28
30
October 1990

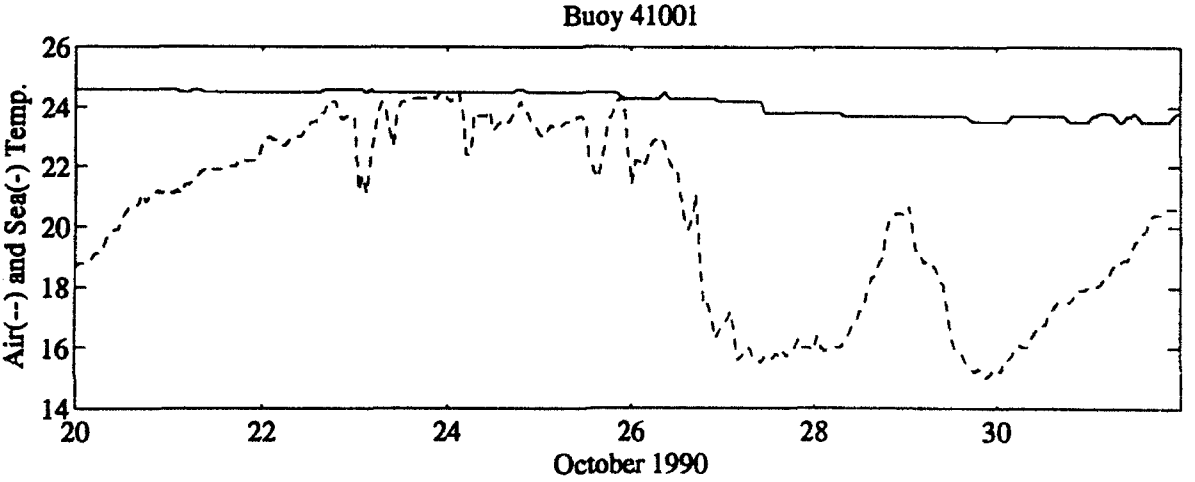

Buoy 41001
Wind Speed (m/s)
25
20
15
10
5
0
20
22
24
26
28
30
October 1990

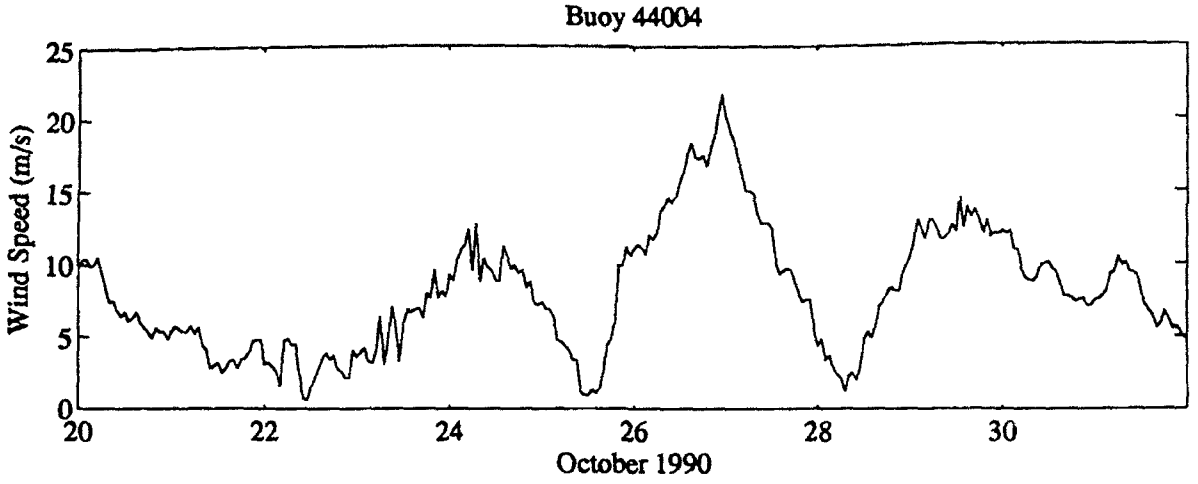

Buoy 41001
Wind Direction (deg)
300
200
100
0
20
22
24
26
28
30
October 1990

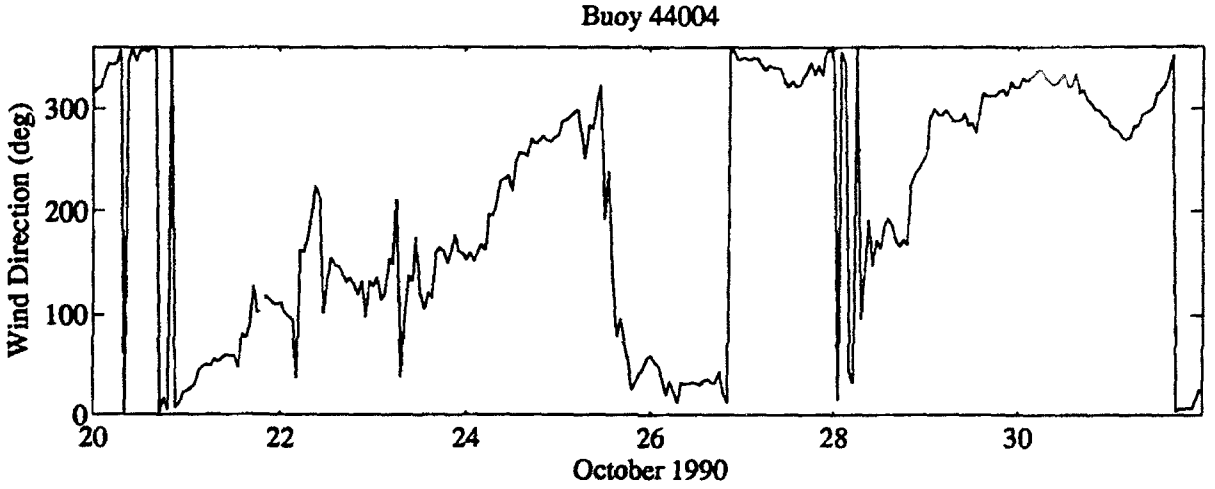

Buoy 41001
Atmospheric Pressure (mb)
1030
1020
1010
1000
990
980
20
22
24
26
28
30
October 1990

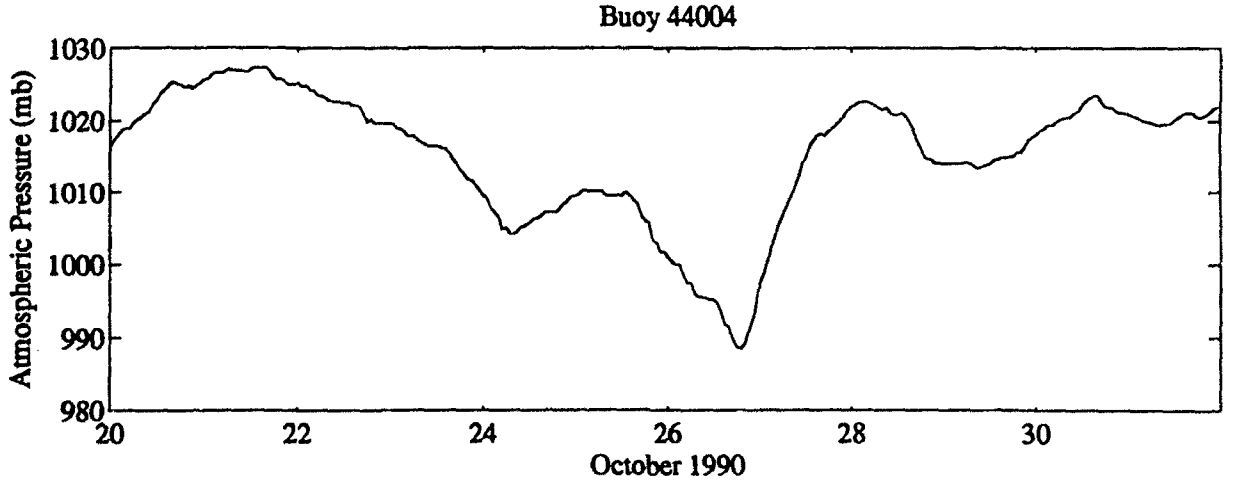

Buoy 41001
Sig. Wave Height (m)
0
2
4
6
8
10
20
22
24
26
28
30
October 1990

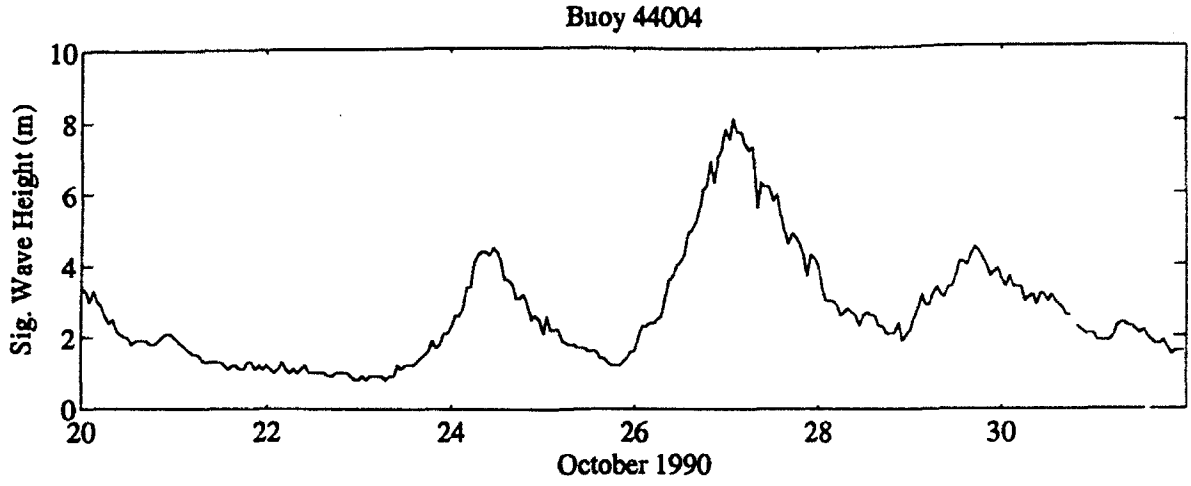

Buoy 41001
Ave.(--) and Peak(-) Period (s)
4
6
8
10
12
14
16
20
22
24
26
28
30
October 1990

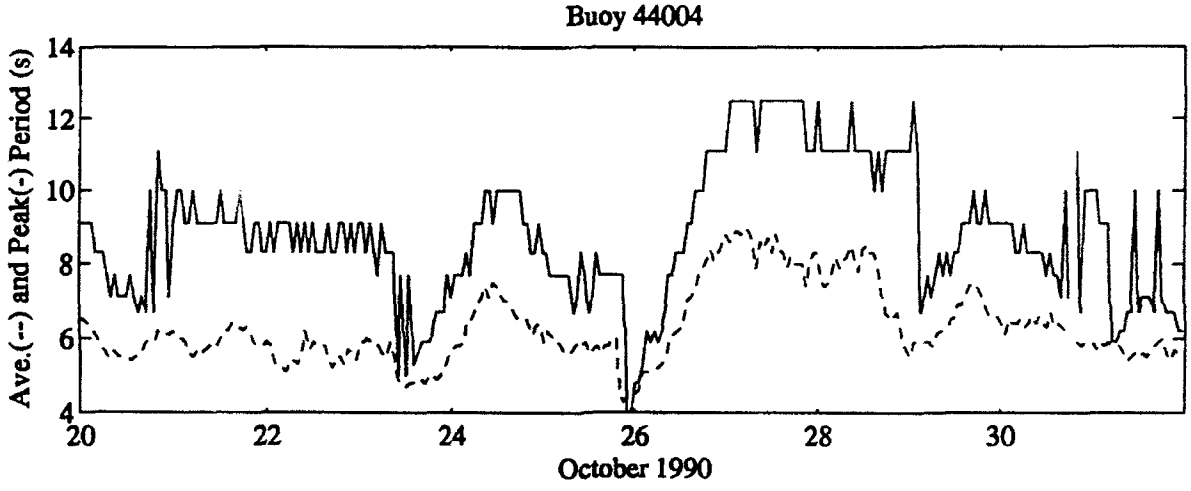

Buoy 41001
Air(--) and Sea(-) Temp.
14
16
18
20
22
24
26
20
22
24
26
28
30
October 1990

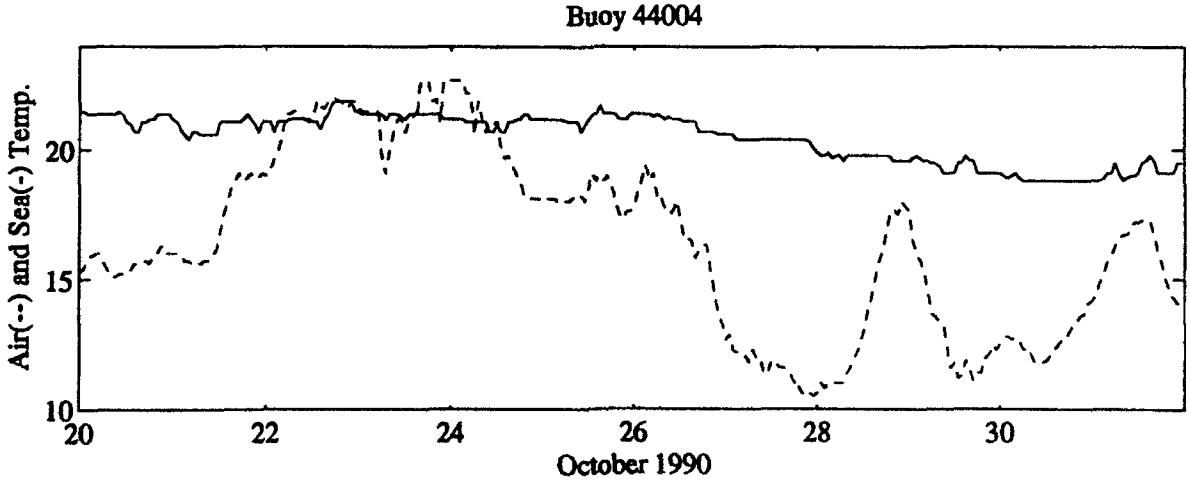

Buoy 44004
Wind Speed (m/s)
25
20
15
10
5
0
20
22
24
26
28
30
October 1990

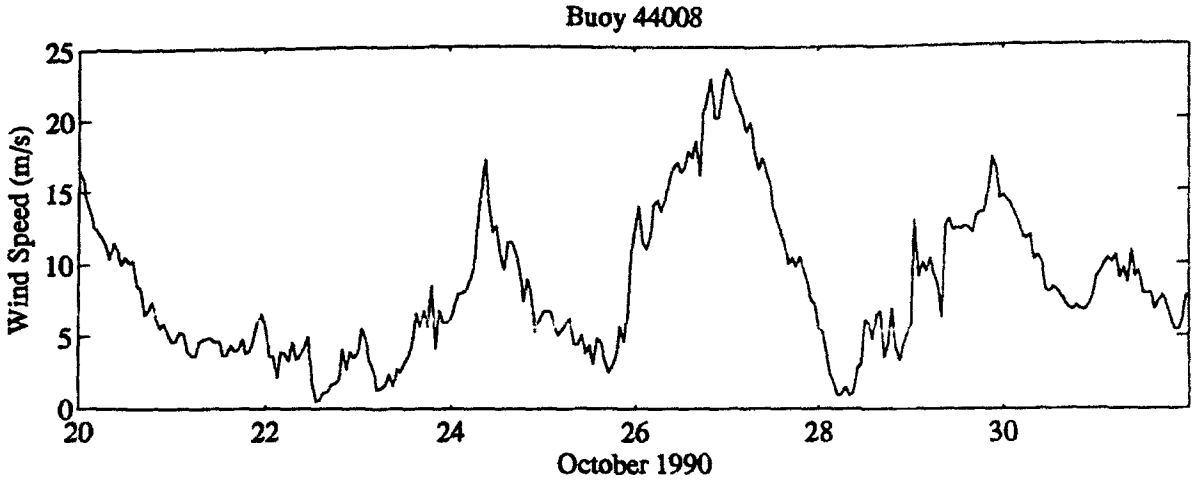

Buoy 44004
Wind Direction (deg)
300
200
100
0
20
22
24
26
28
30
October 1990

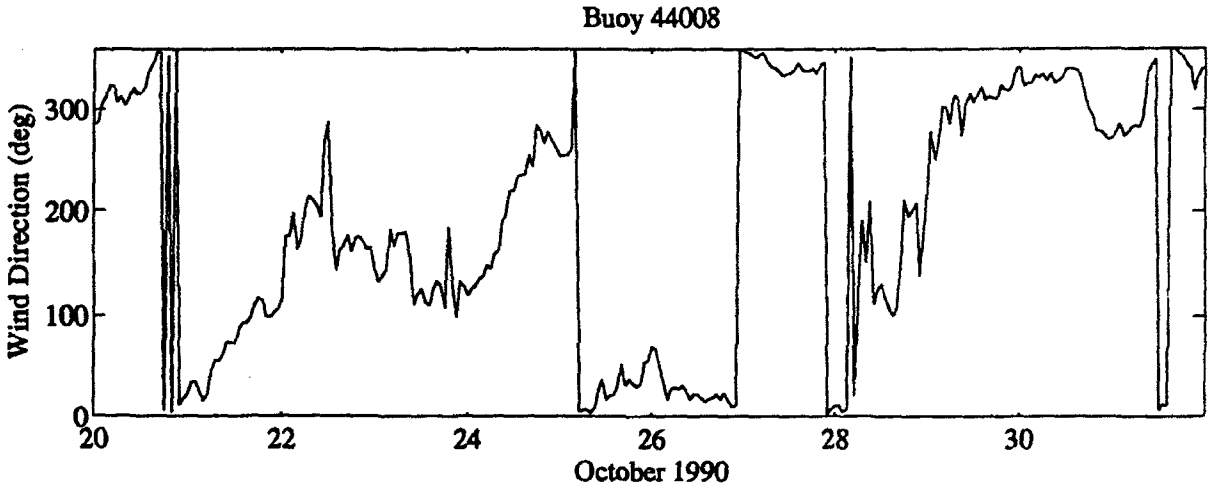

Buoy 44004
Atmospheric Pressure (mb)
1030
1020
1010
1000
990
980
20
22
24
26
28
30
October 1990

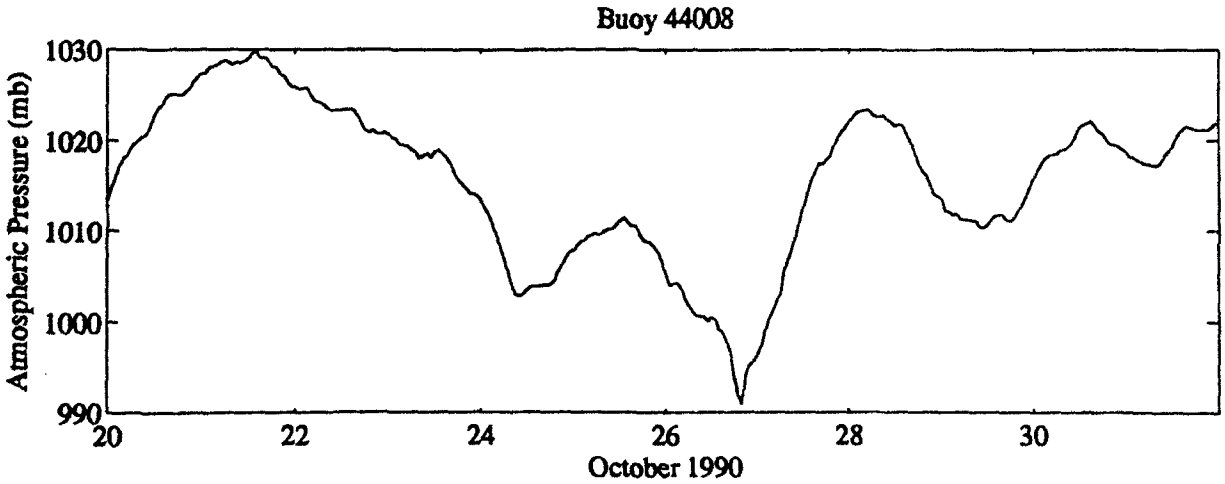

Buoy 44004
Sig. Wave Height (m)
0
2
4
6
8
10
20
22
24
26
28
30
October 1990

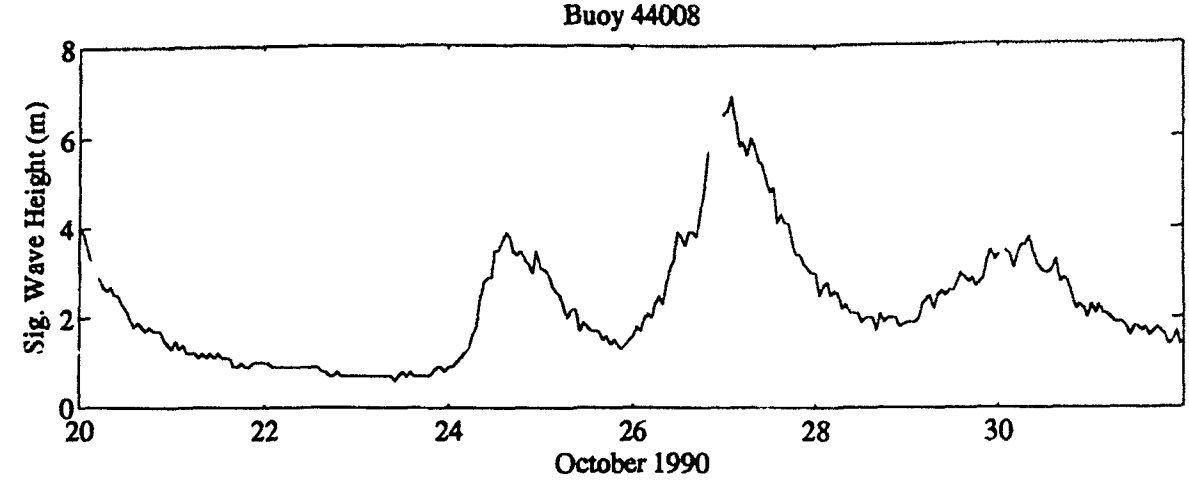

Buoy 44004
Ave.(--) and Peak(-) Period (s)
4
6
8
10
12
14
20
22
24
26
28
30
October 1990

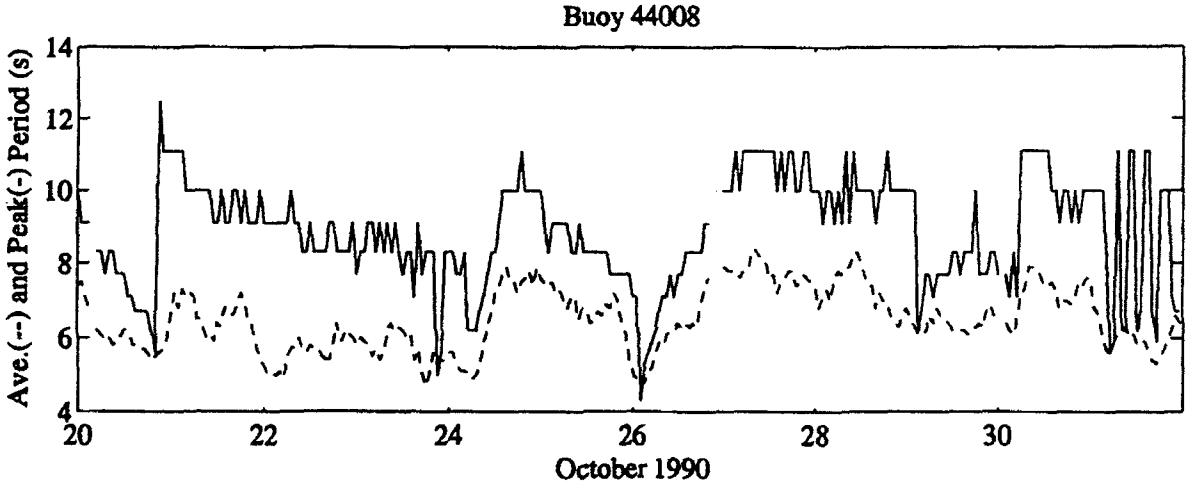

Buoy 44004
Air(--) and Sea(-) Temp.
10
15
20
20
22
24
26
28
30
October 1990


Buoy 44008
Wind Speed (m/s)
25
20
15
10
5
0
20
22
24
26
28
30
October 1990


Buoy 44008
Wind Direction (deg)
300
200
100
0
20
22
24
26
28
30
October 1990


Buoy 44008
Atmospheric Pressure (mb)
1030
1020
1010
1000
990
20
22
24
26
28
30
October 1990


Buoy 44008
Sig. Wave Height (m)
0
2
4
6
8
20
22
24
26
28
30
October 1990


Buoy 44008
Ave.(--) and Peak(-) Period (s)
4
6
8
10
12
14
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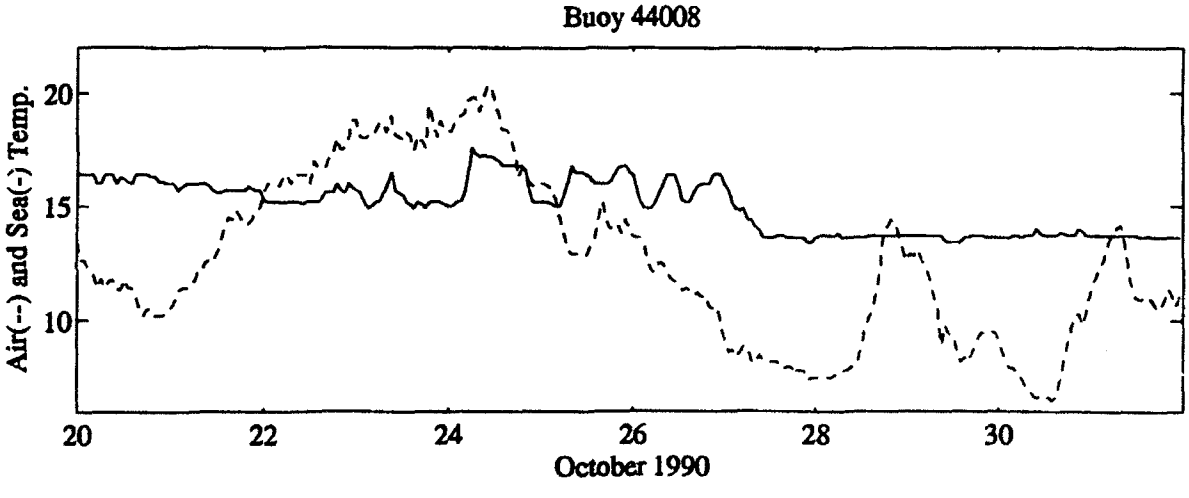
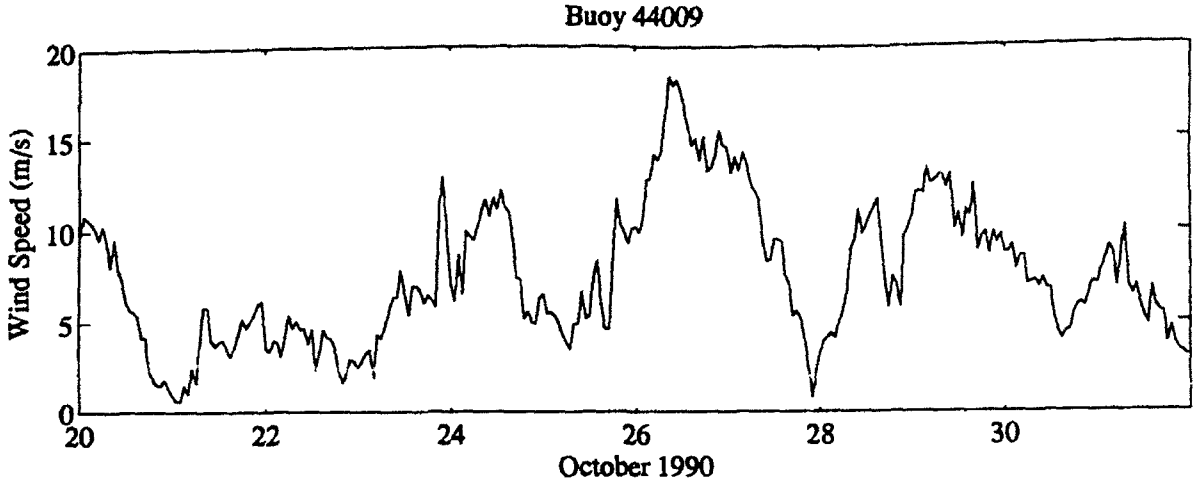
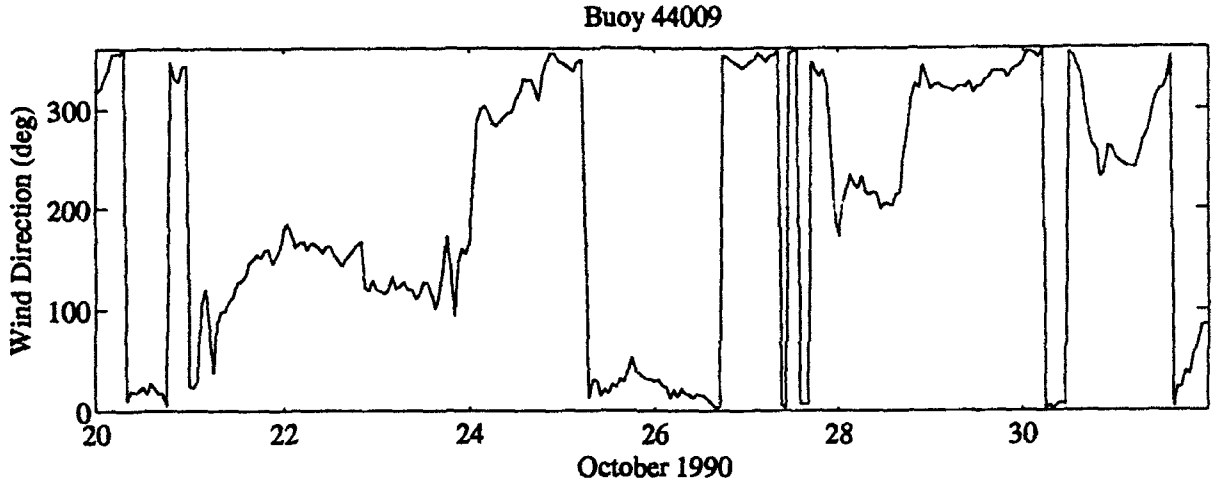
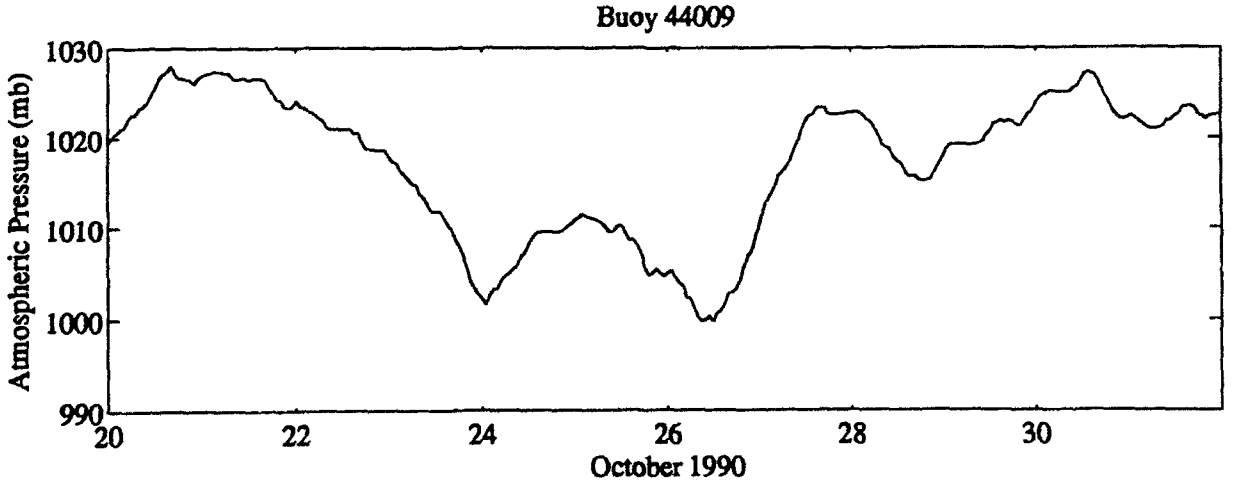
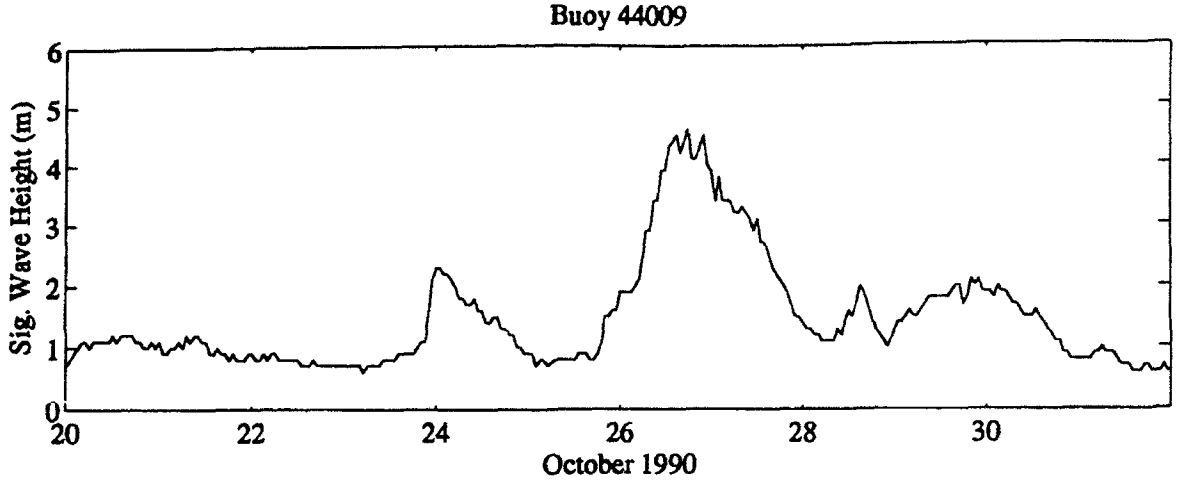
22
24
26
28
30
October 1990

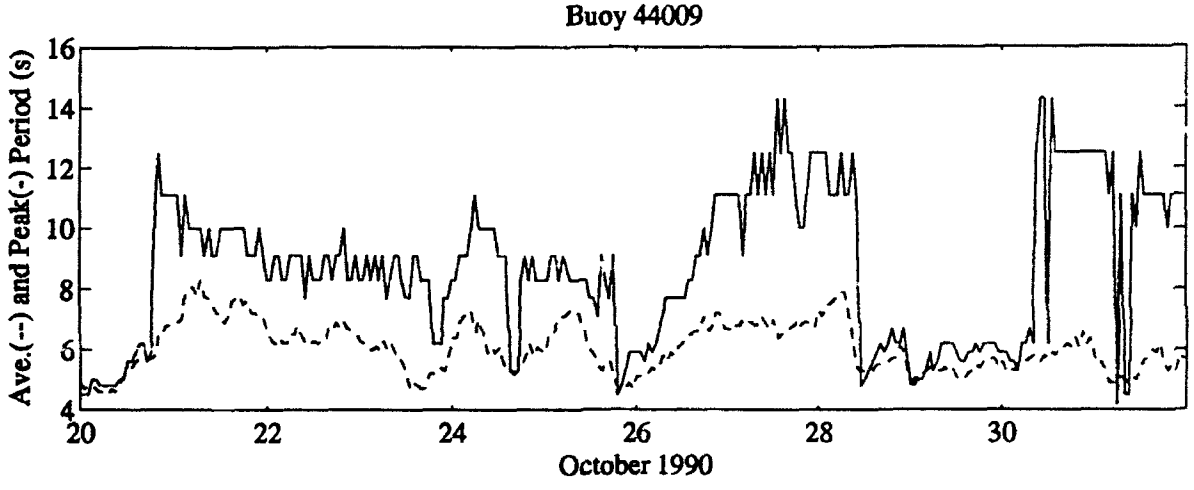

Buoy 44008
Air(--) and Sea(-) Temp.
10
15
20
20
22
24
26
28
30
October 1990

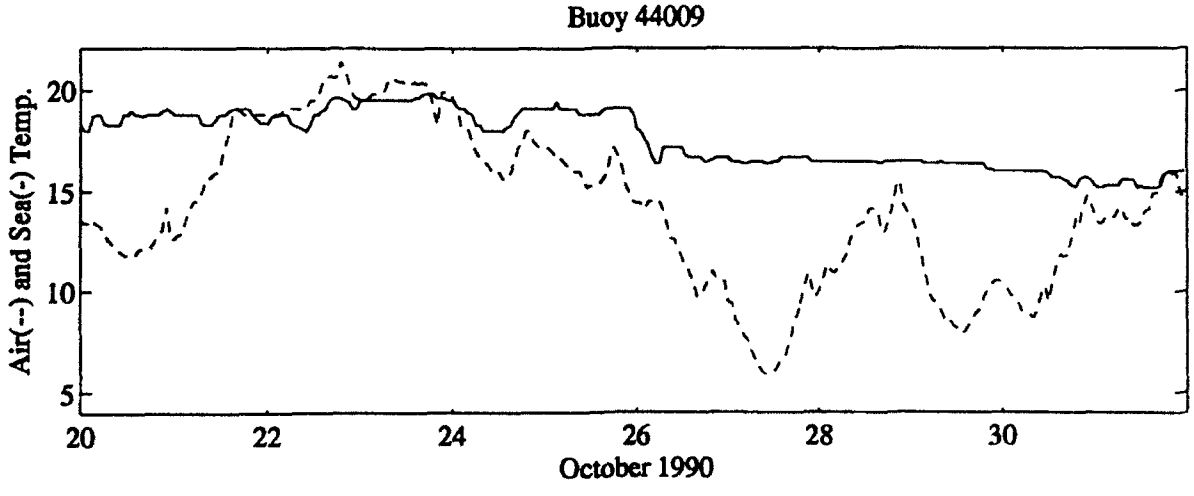

Buoy 44009
Wind Speed (m/s)
0
5
10
15
20
20
22
24
26
28
30
October 1990

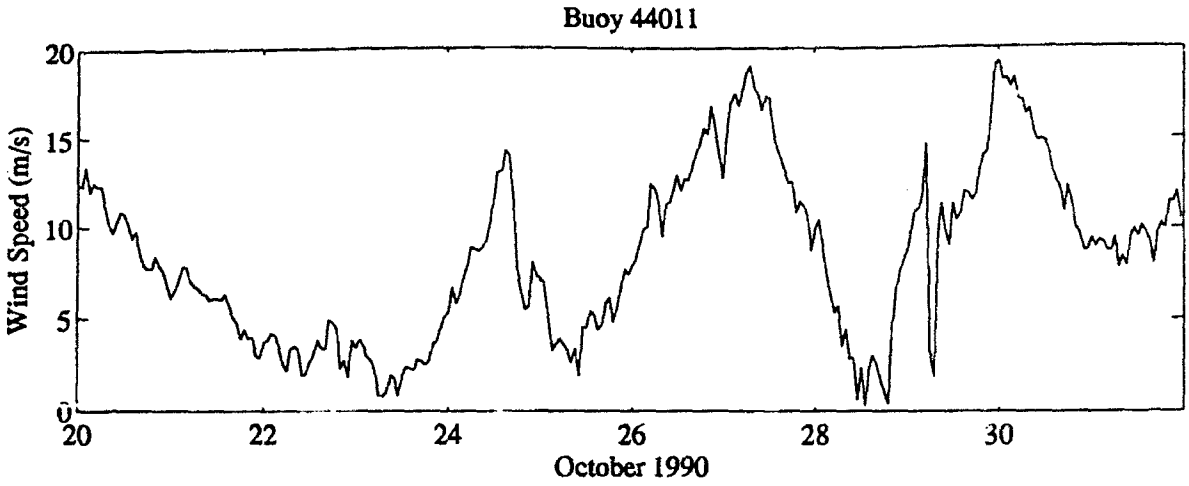

Buoy 44009
Wind Direction (deg)
0
100
200
300
20
22
24
26
28
30
October 1990

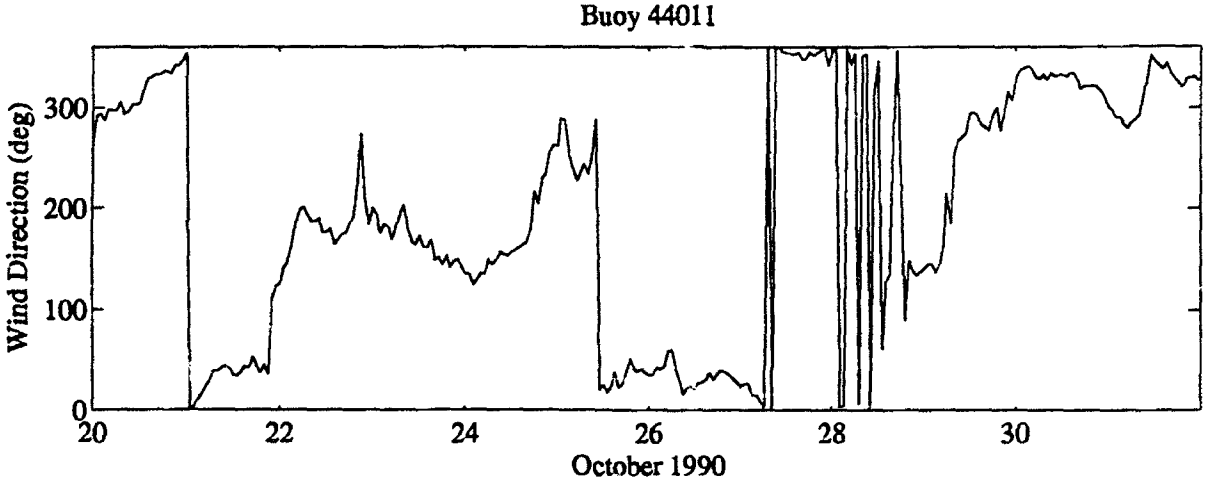

Buoy 44009
Atmospheric Pressure (mb)
990
1000
1010
1020
1030
20
22
24
26
28
30
October 1990

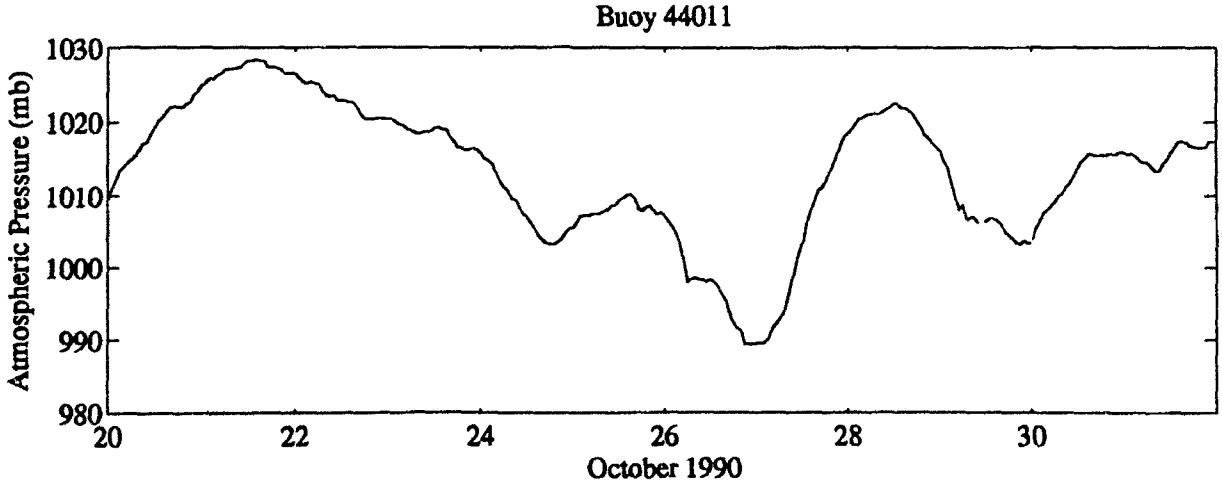

Buoy 44009
Sig. Wave Height (m)
0
1
2
3
4
5
6
20
22
24
26
28
30
October 1990

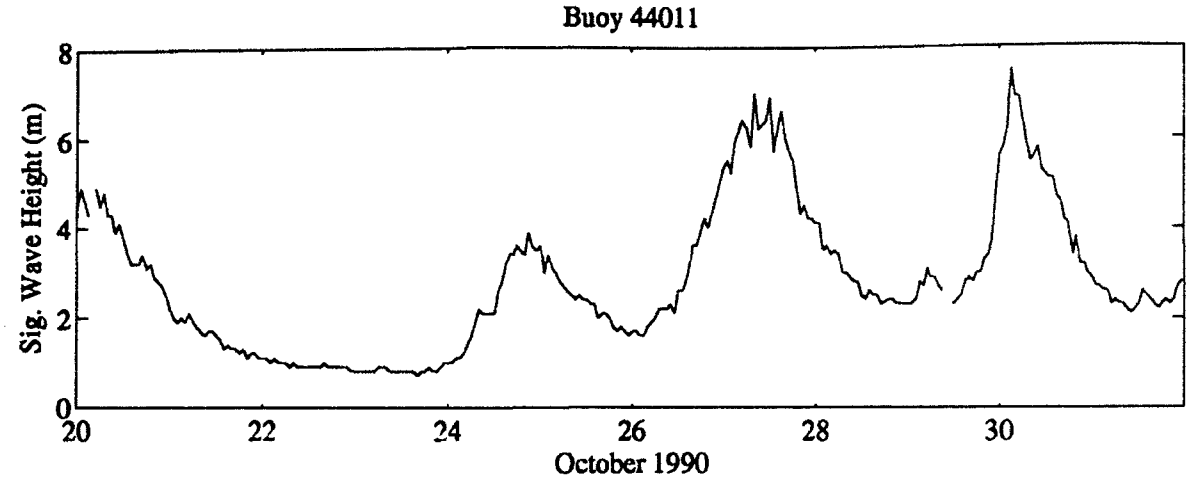

Buoy 44009
Ave.(--) and Peak(-) Period (s)
4
6
8
10
12
14
16
20
22
24
26
28
30
October 1990

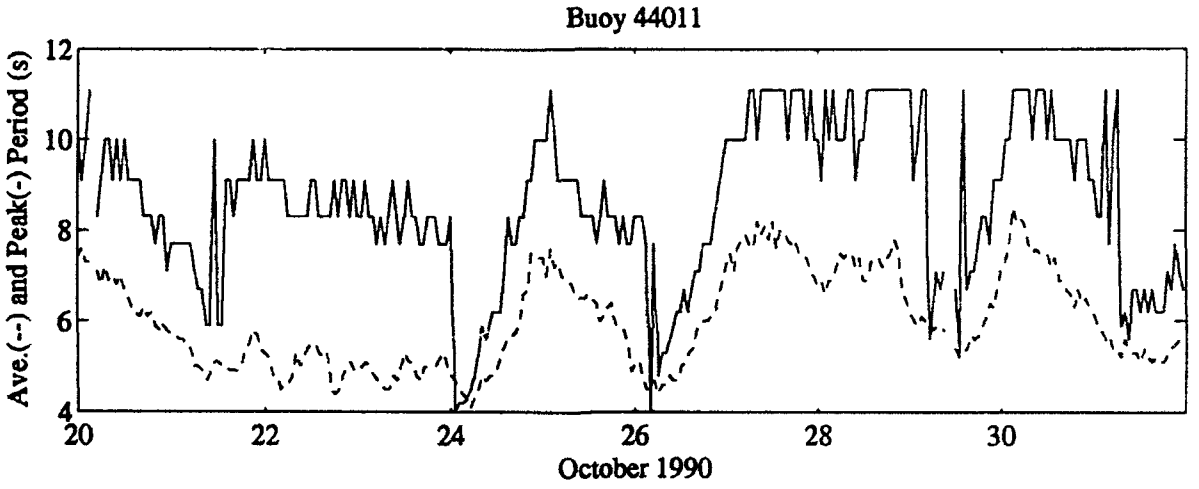

Buoy 44009
Air(--) and Sea(-) Temp.
5
10
15
20
20
22
24
26
28
30
October 1990

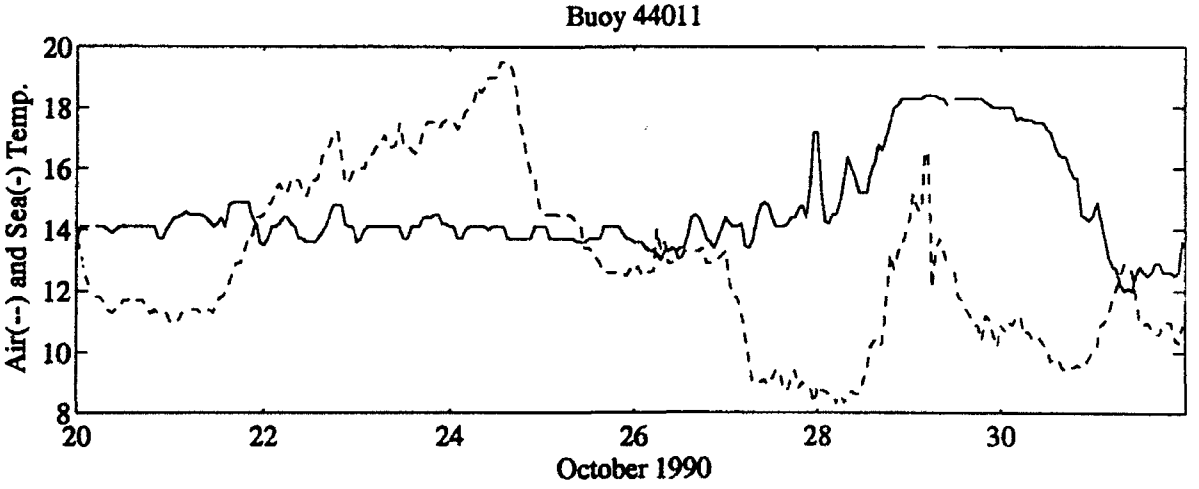

Buoy 44011
Wind Speed (m/s)
0
5
10
15
20
20
22
24
26
28
30
October 1990

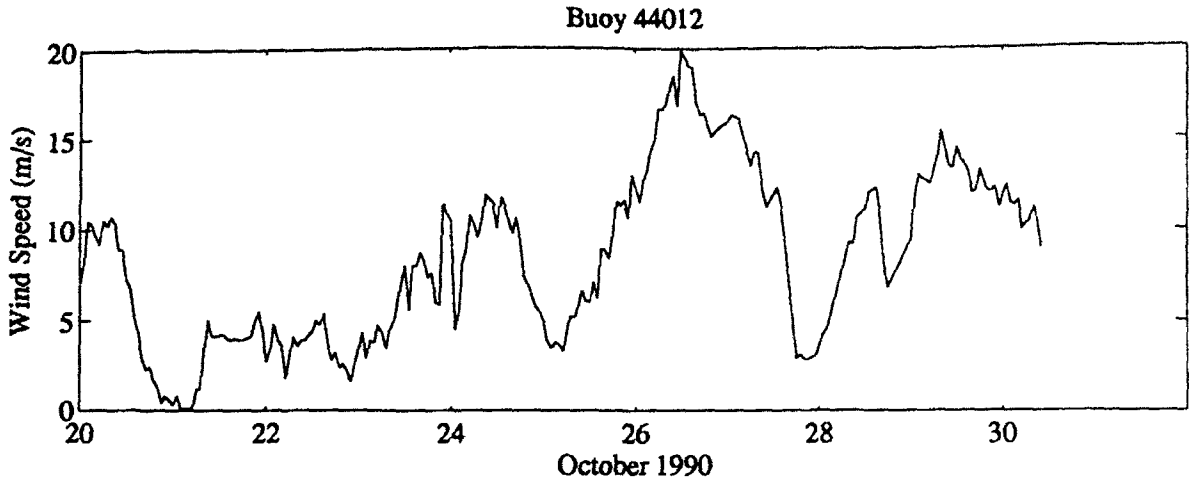

Buoy 44011
Wind Direction (deg)
0
100
200
300
20
22
24
26
28
30
October 1990

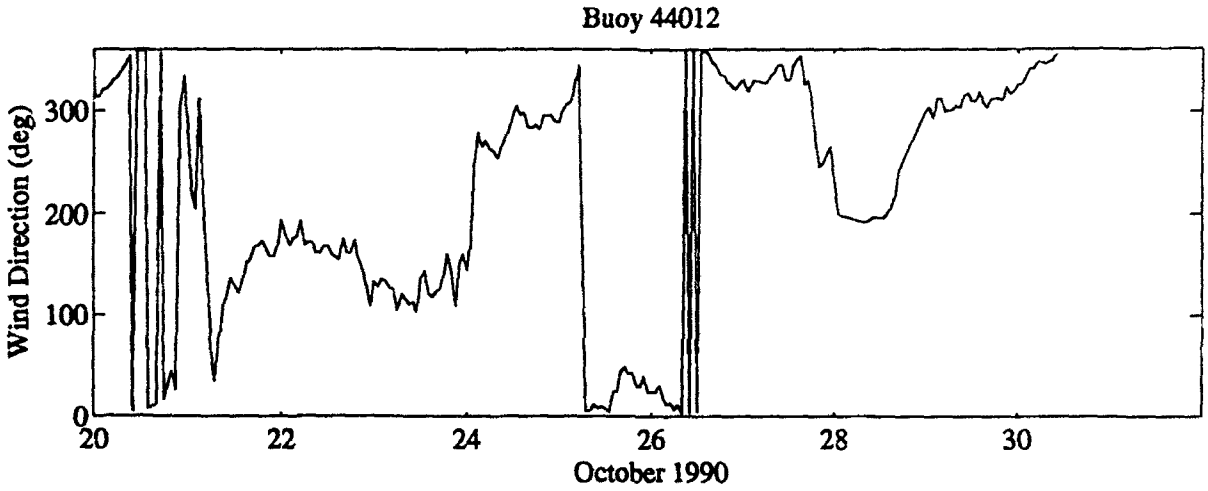

Buoy 44011
Atmospheric Pressure (mb)
980
990
1000
1010
1020
1030
20
22
24
26
28
30
October 1990

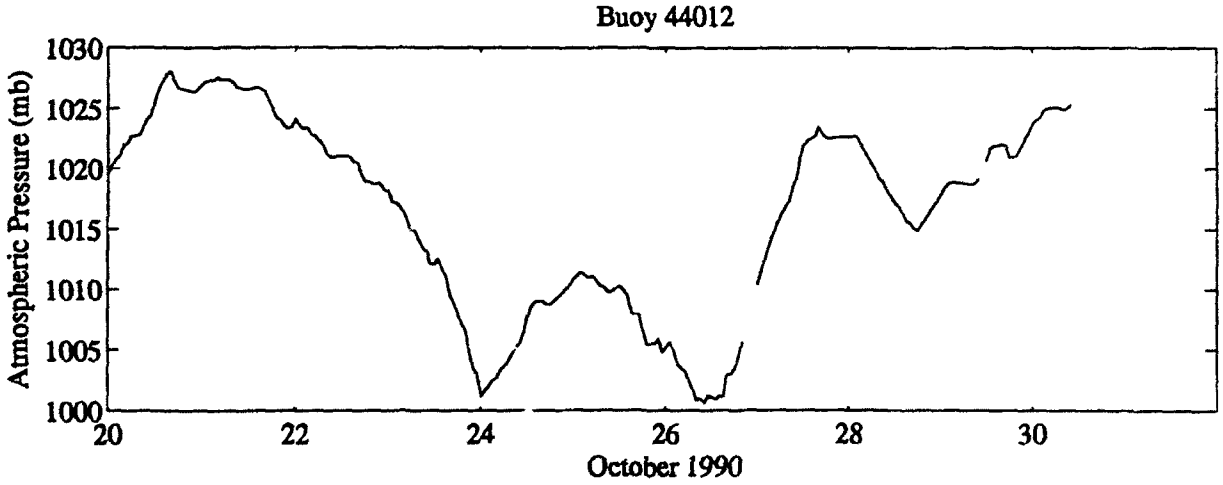

Buoy 44011
Sig. Wave Height (m)
0
2
4
6
8
20
22
24
26
28
30
October 1990

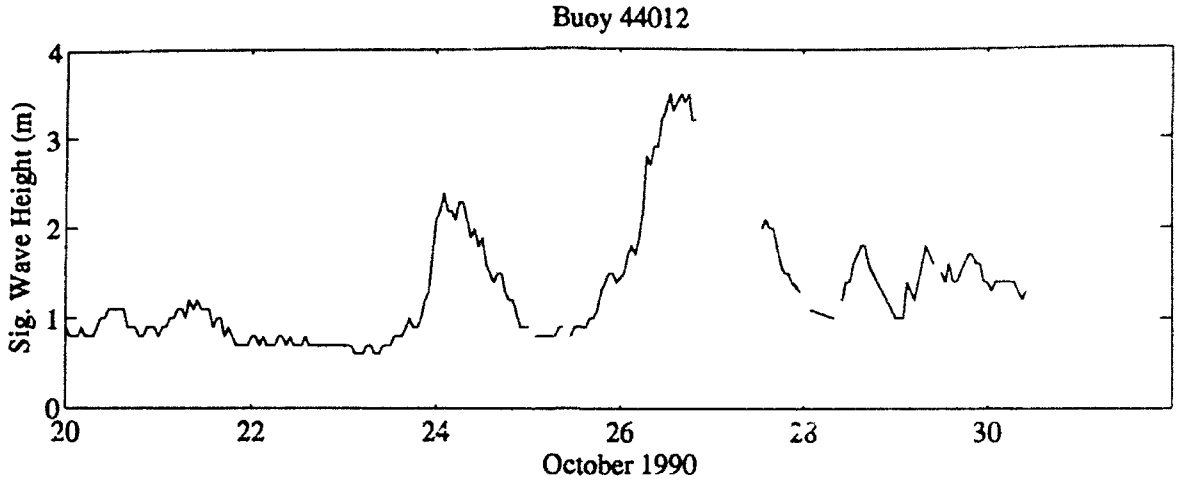

Buoy 44011
Ave.(--) and Peak(-) Period (s)
4
6
8
10
12
20
22
24
26
28
30
October 1990

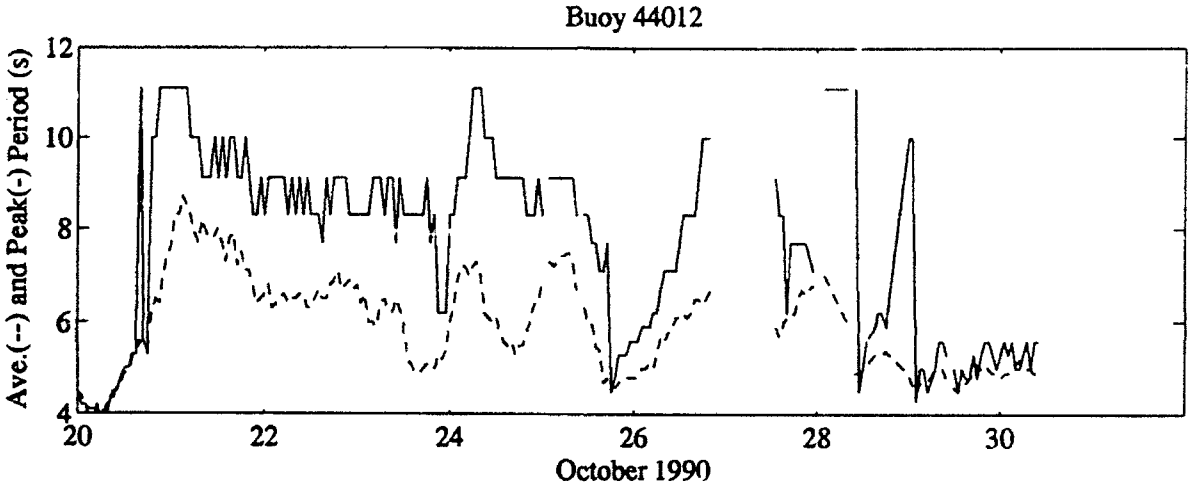

Buoy 44011
Air(--) and Sea(-) Temp.
8
10
12
14
16
18
20
20
22
24
26
28
30
October 1990

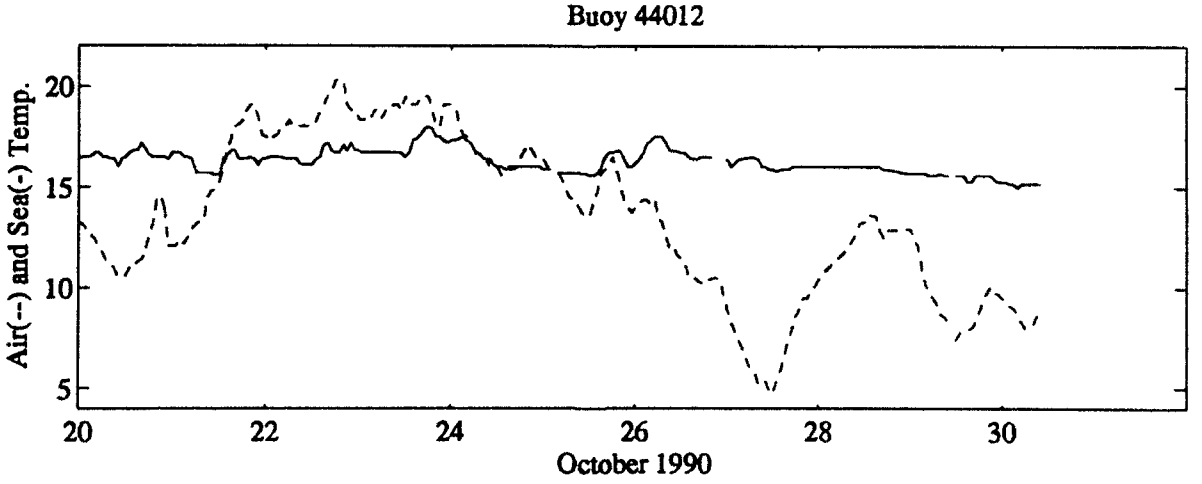

Buoy 44012
Wind Speed (m/s)
0
5
10
15
20
20
22
24
26
28
30
October 1990

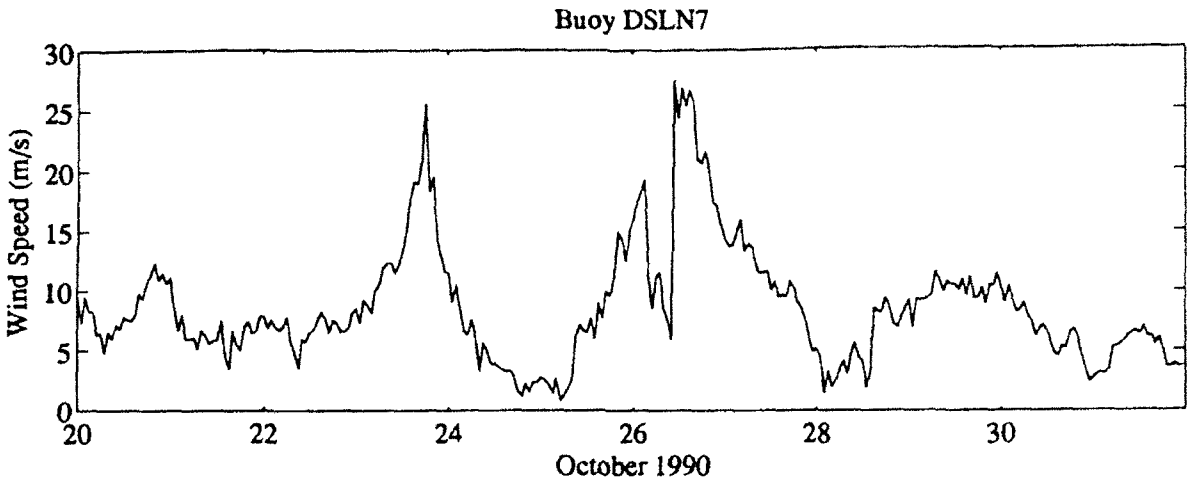

Buoy 44012
Wind Direction (deg)
0
100
200
300
20
22
24
26
28
30
October 1990

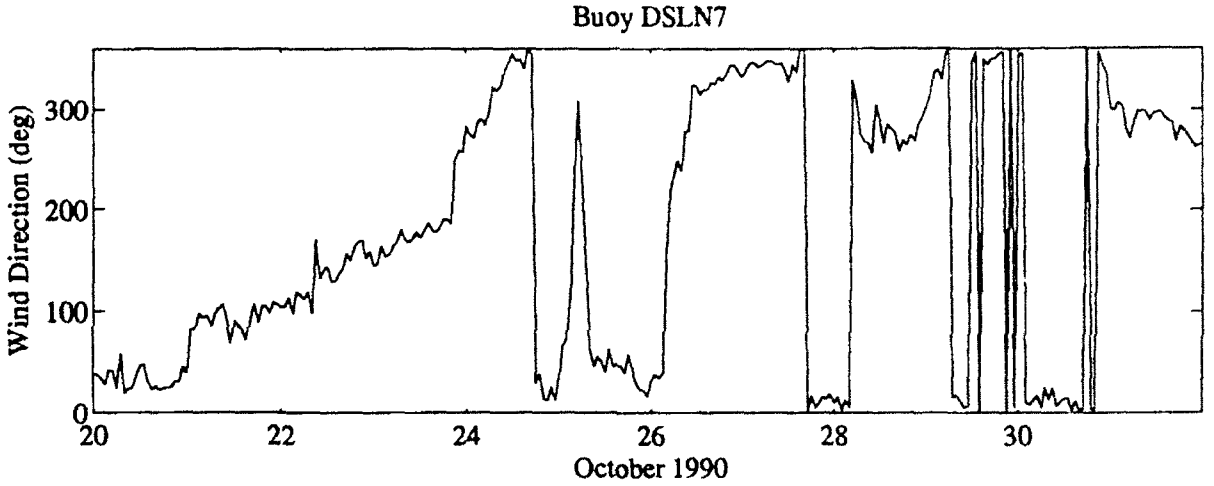

Buoy 44012
Atmospheric Pressure (mb)
1000
1005
1010
1015
1020
1025
1030
20
22
24
26
28
30
October 1990

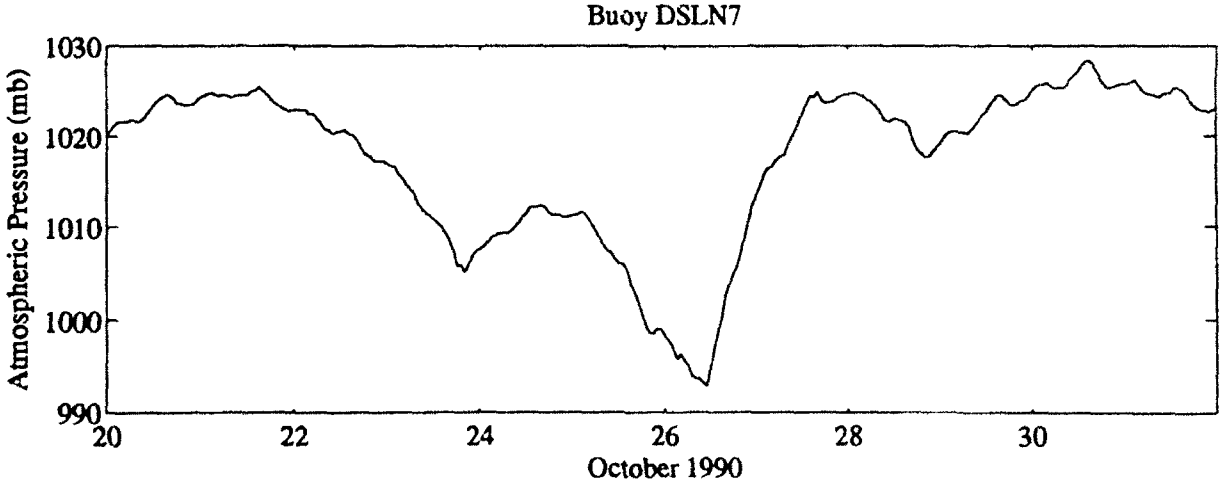

Buoy 44012
Sig. Wave Height (m)
0
1
2
3
4
20
22
24
26
28
30
October 1990

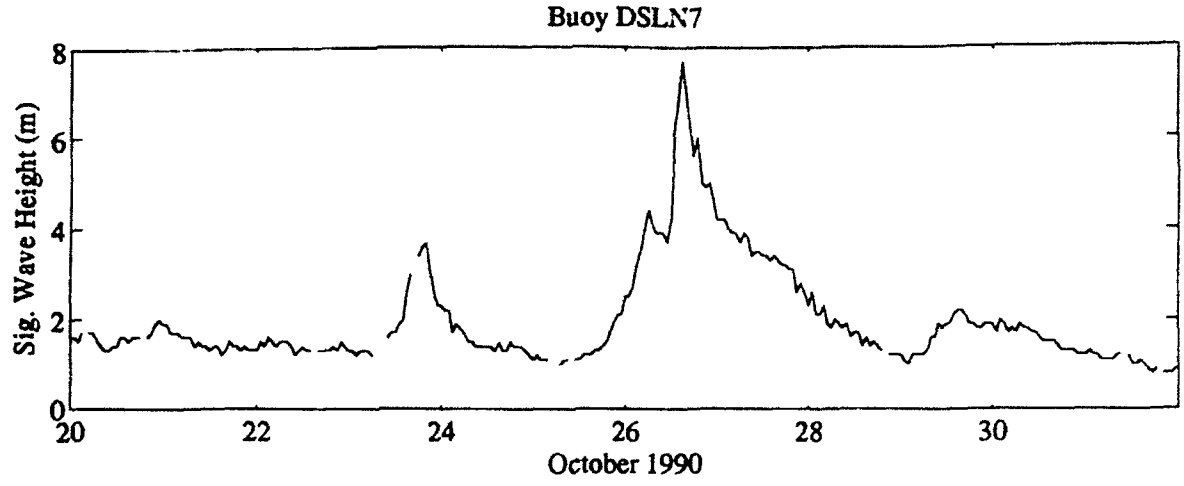

Buoy 44012
Ave.(--) and Peak(-) Period (s)
4
6
8
10
12
20
22
24
26
28
30
October 1990

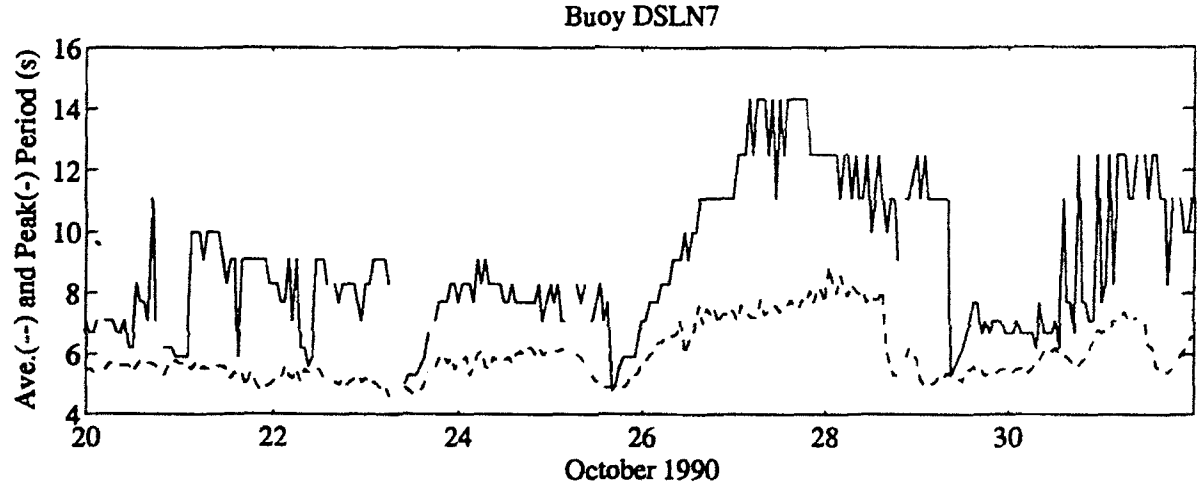

Buoy 44012
Air(--) and Sea(-) Temp.
5
10
15
20
20
22
24
26
28
30
October 1990

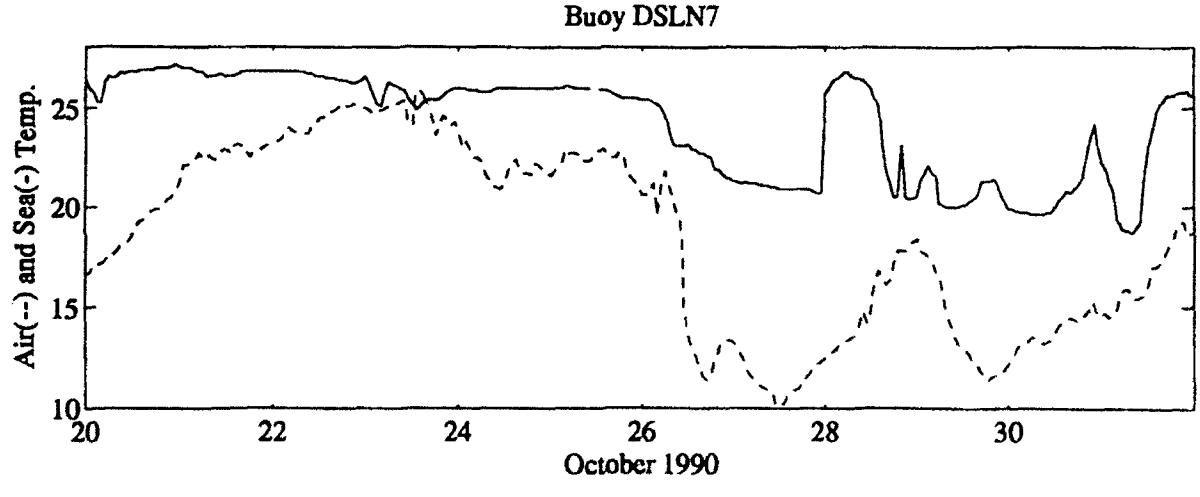

Buoy DSLN7
Wind Speed (m/s)
0
5
10
15
20
25
30
20
22
24
26
28
30
October 1990

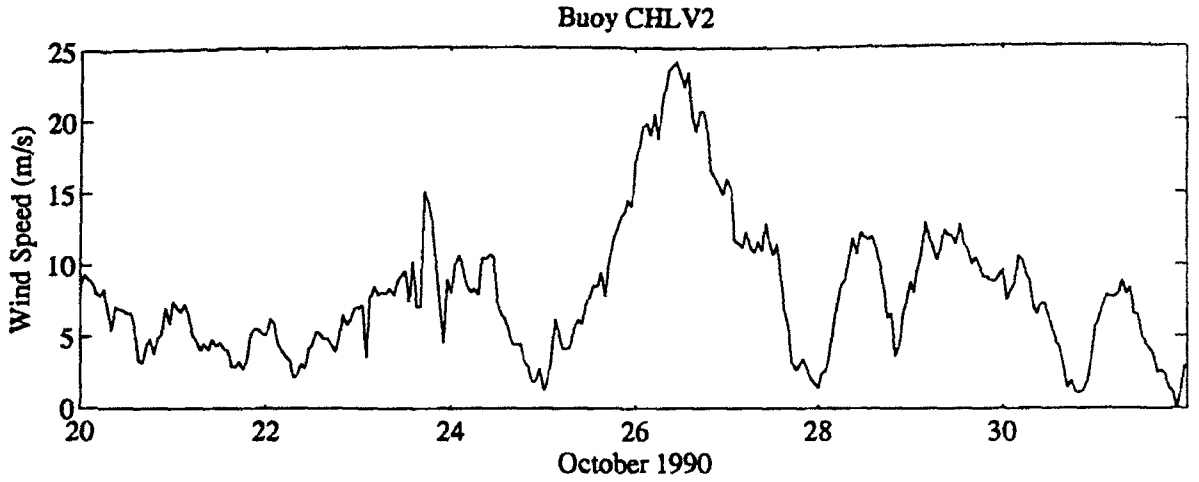

Buoy DSLN7
Wind Direction (deg)
0
100
200
300
20
22
24
26
28
30
October 1990

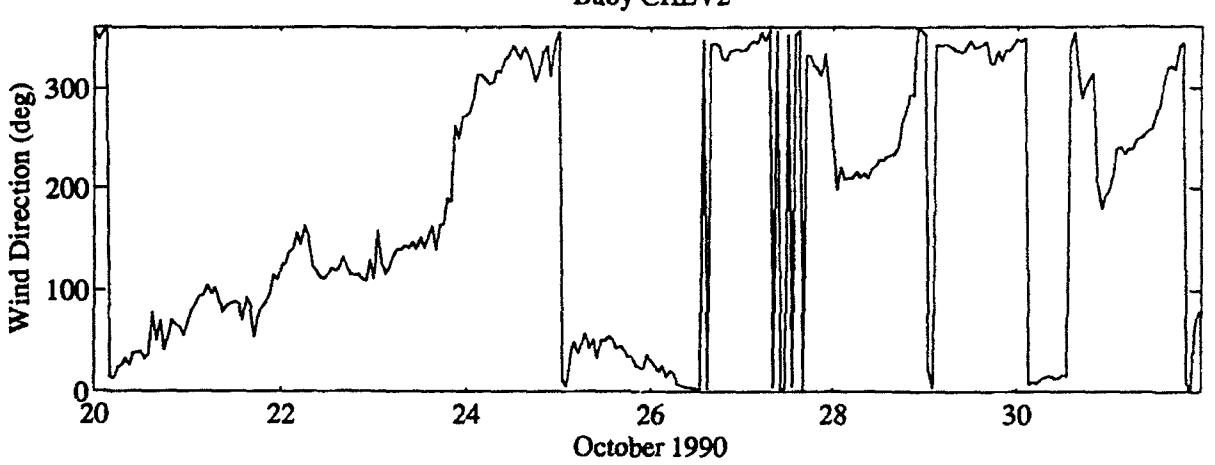

Buoy DSLN7
Atmospheric Pressure (mb)
990
1000
1010
1020
1030
20
22
24
26
28
30
October 1990

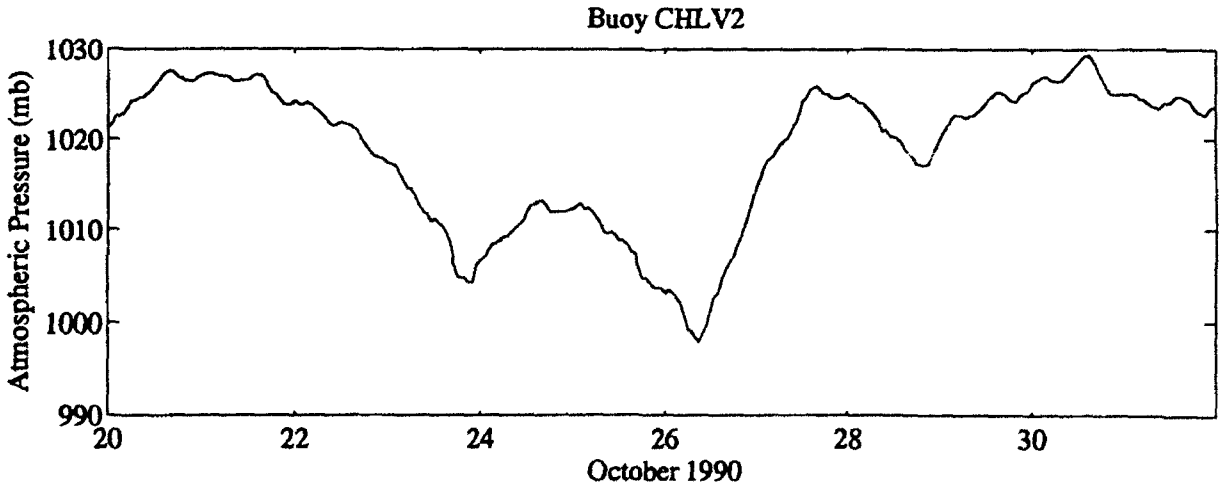

Buoy DSLN7
Sig. Wave Height (m)
0
2
4
6
8
20
22
24
26
28
30
October 1990

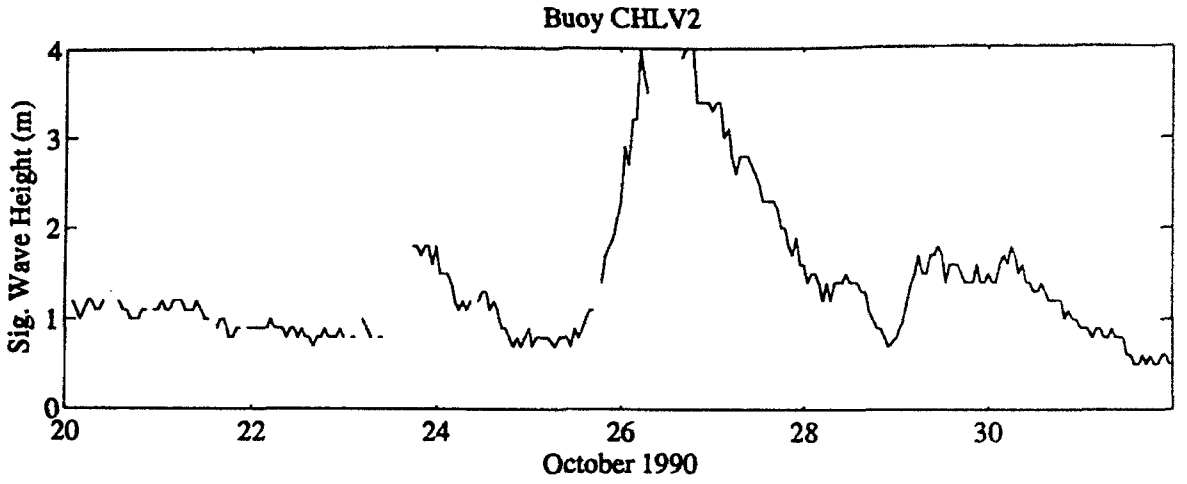

Buoy DSLN7
Ave.(--) and Peak(-) Period (s)
4
6
8
10
12
14
16
20
22
24
26
28
30
October 1990

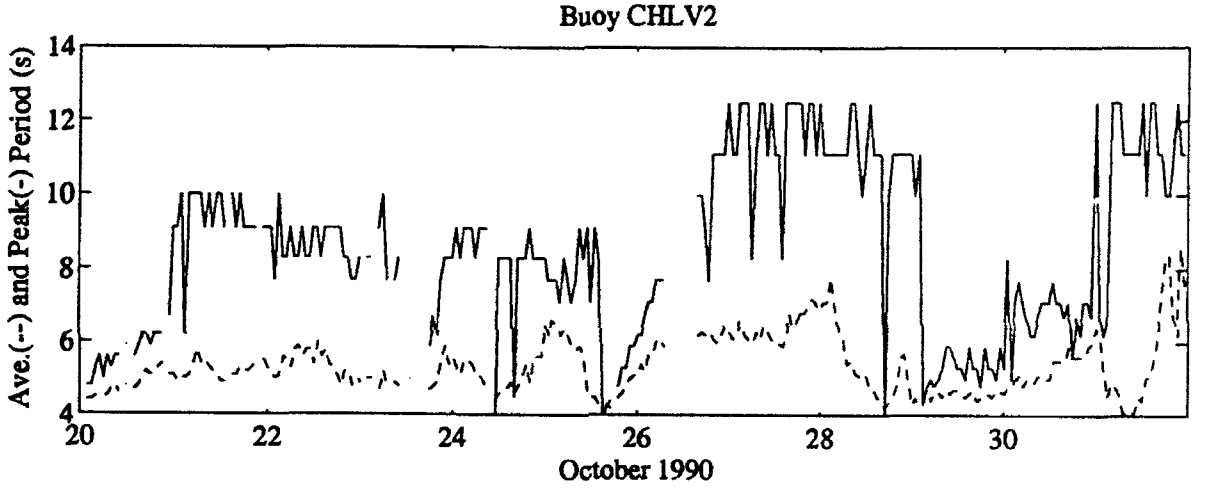

Buoy DSLN7
Air(--) and Sea(-) Temp.
10
15
20
25
20
22
24
26
28
30
October 1990

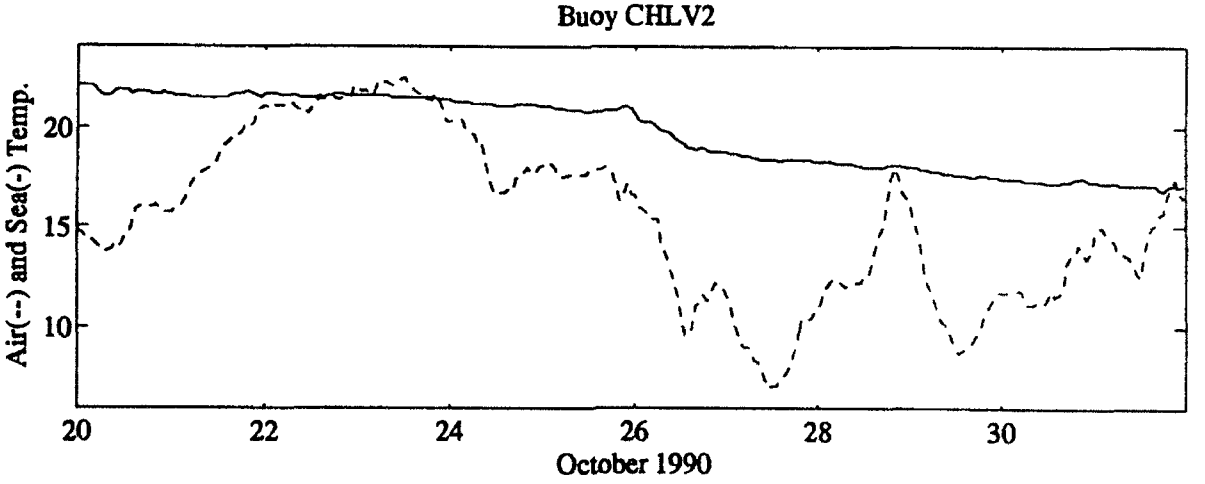

Buoy CHLV2
Wind Speed (m/s)
25
20
15
10
5
0
20
22
24
26
28
30
October 1990

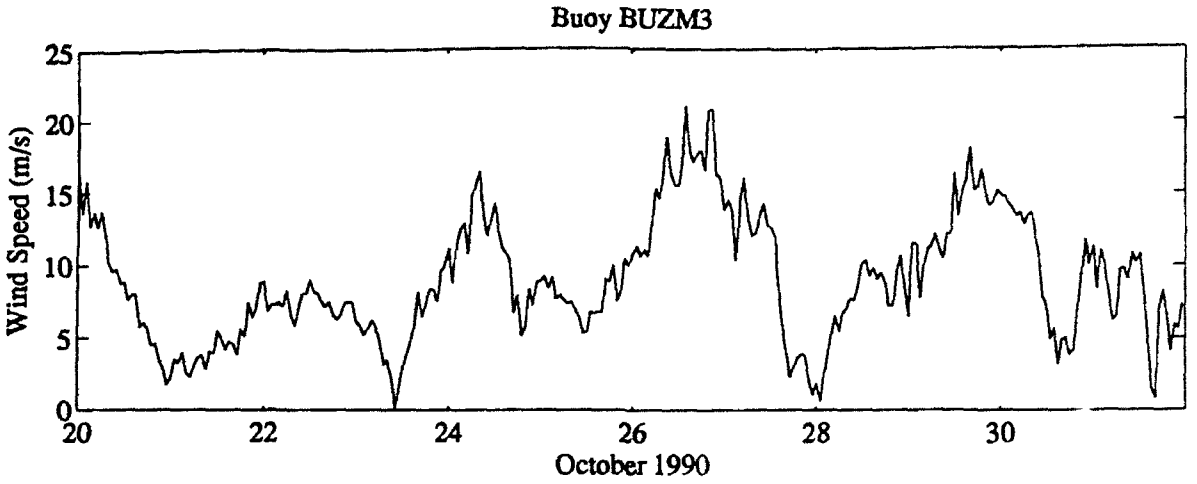

Buoy CHLV2
Wind Direction (deg)
300
200
100
0
20
22
24
26
28
30
October 1990

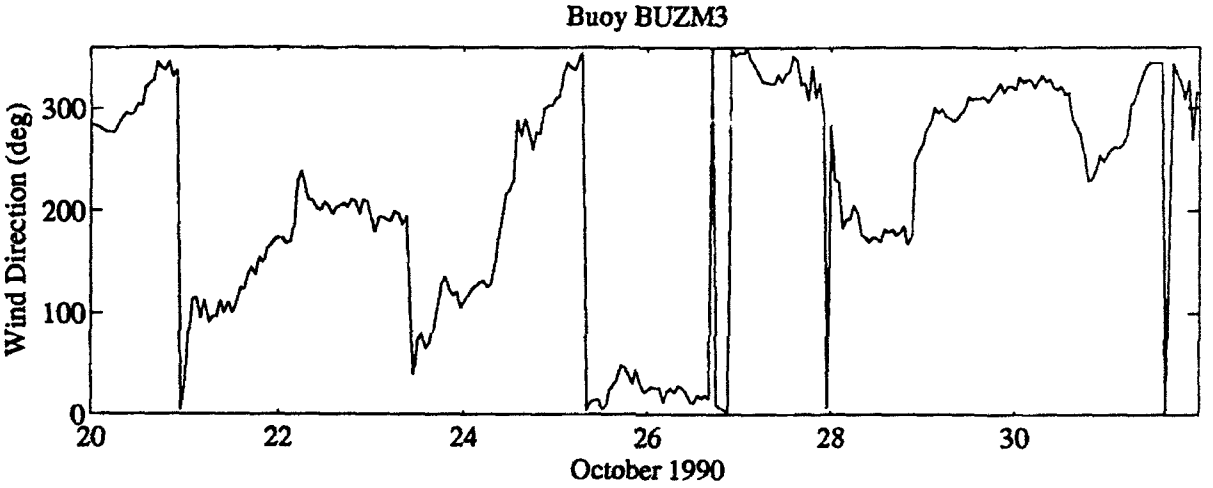

Buoy CHLV2
Atmospheric Pressure (mb)
1030
1020
1010
1000
990
20
22
24
26
28
30
October 1990

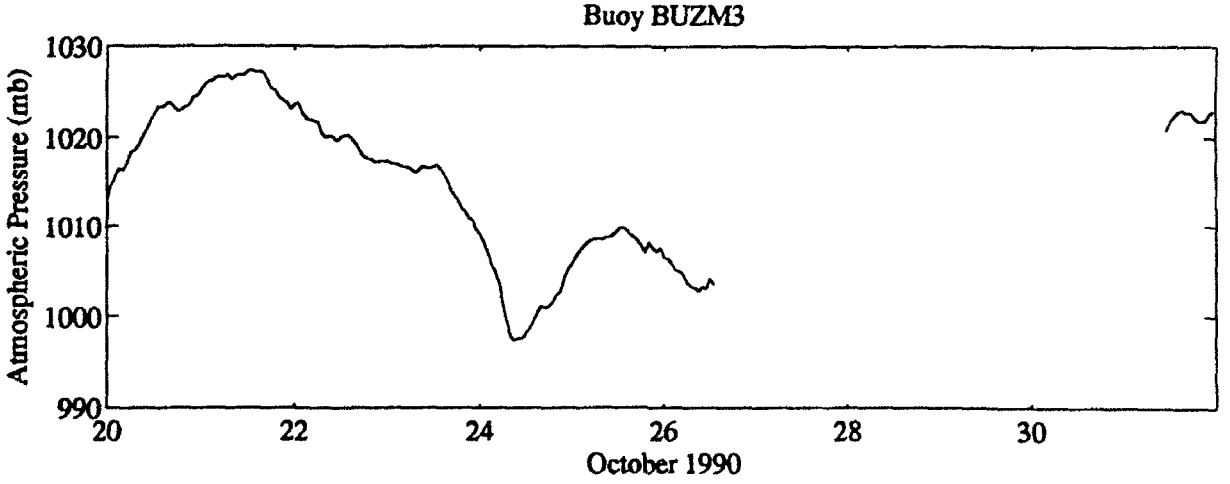

Buoy CHLV2
Sig. Wave Height (m)
0
1
2
3
4
20
22
24
26
28
30
October 1990

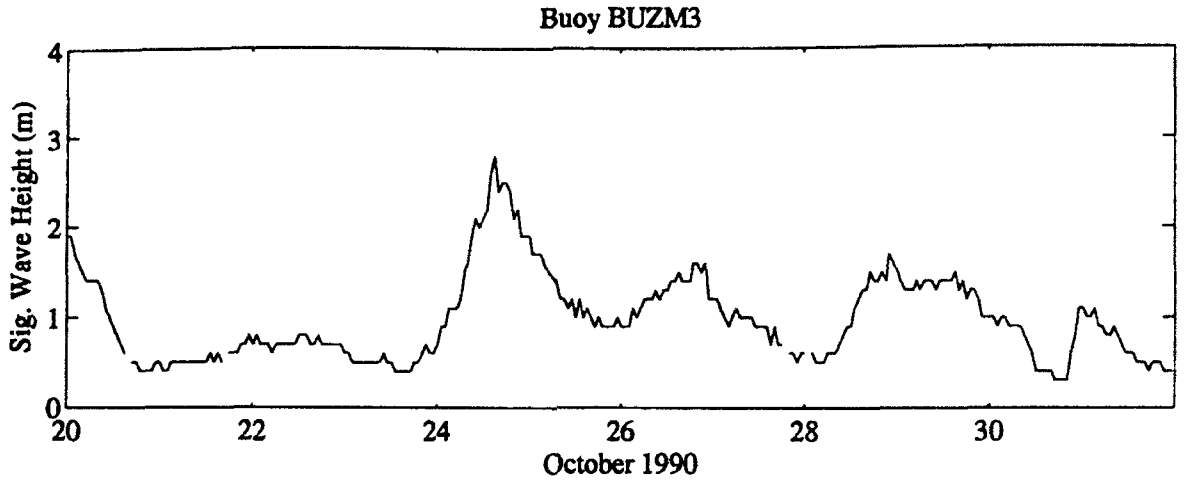

Buoy CHLV2
Ave.(--) and Peak(-) Period (s)
4
6
8
10
12
14
20
22
24
26
28
30
October 1990

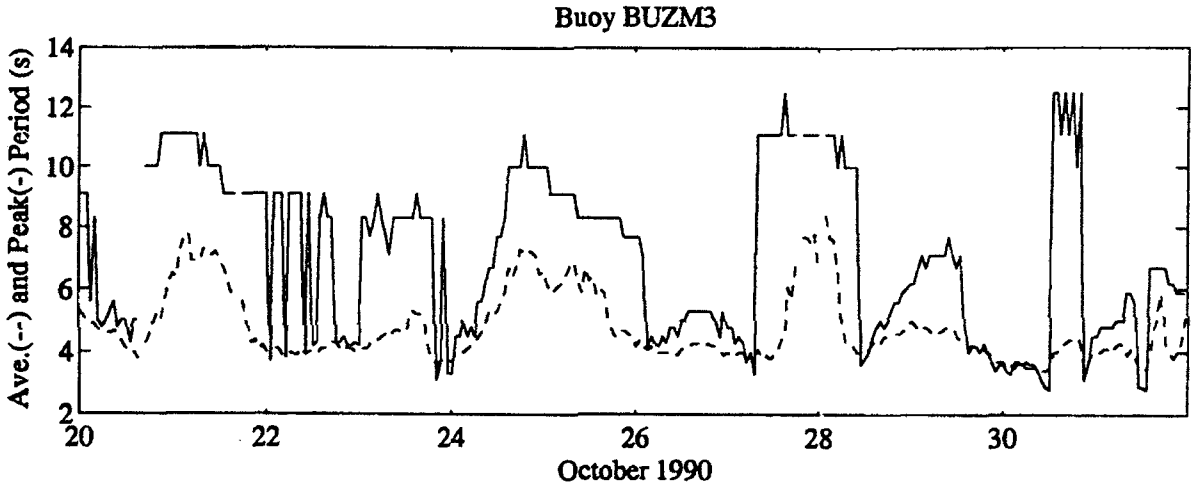

Buoy CHLV2
Air(--) and Sea(-) Temp.
10
15
20
20
22
24
26
28
30
October 1990

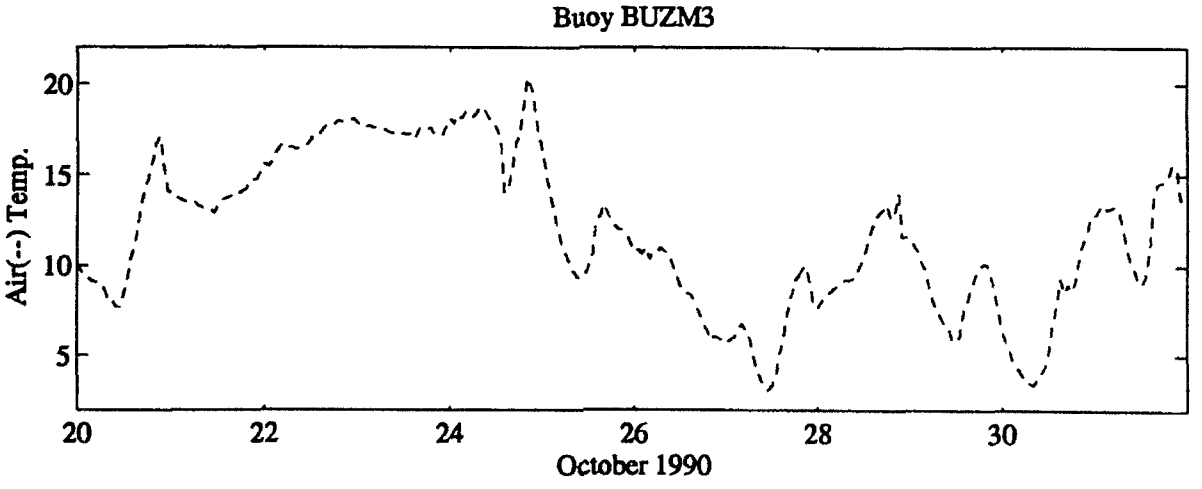

Buoy BUZM3
Wind Speed (m/s)
25
20
15
10
5
0
20
22
24
26
28
30
October 1990


Buoy BUZM3
Wind Direction (deg)
300
200
100
0
20
22
24
26
28
30
October 1990


Buoy BUZM3
Atmospheric Pressure (mb)
1030
1020
1010
1000
990
20
22
24
26
28
30
October 1990


Buoy BUZM3
Sig. Wave Height (m)
0
1
2
3
4
20
22
24
26
28
30
October 1990


Buoy BUZM3
Ave.(--) and Peak(-) Period (s)
2
4
6
8
10
12
14
20
22
24
26
28
30
October 1990

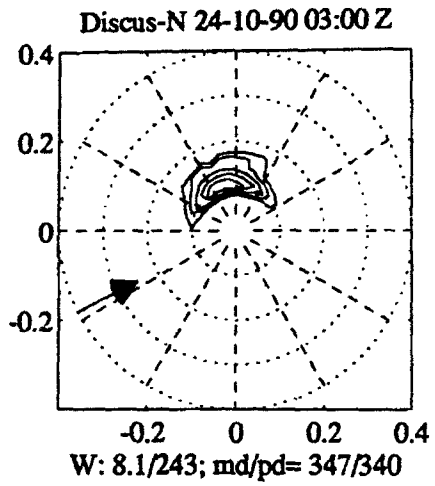

Buoy BUZM3
Air(--) Temp.
5
10
15
20
20
22
24
26
28
30
October 1990

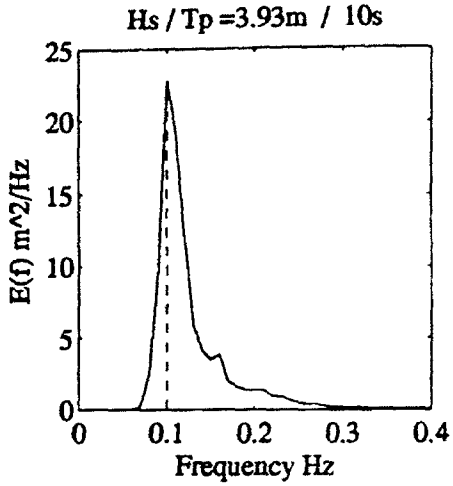
Appendix B: Directional Wave Spectra from SWADE Buoys

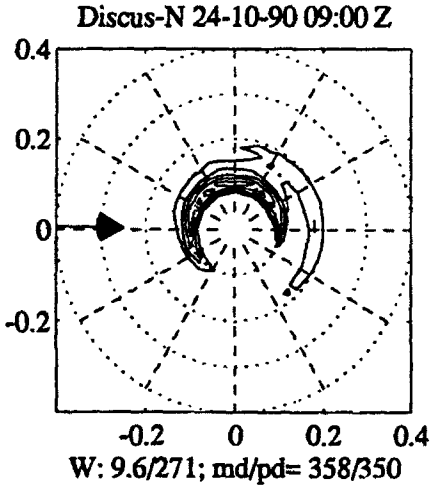
Plots of the directional wave spectra and the corresponding one-dimensional frequency spectra are presented in this appendix for buoys D-North, D-East and CERC (44014) every 3 hr from 24 October 1990, 03:00 GMT to 29 October 1990, 00:00 GMT.

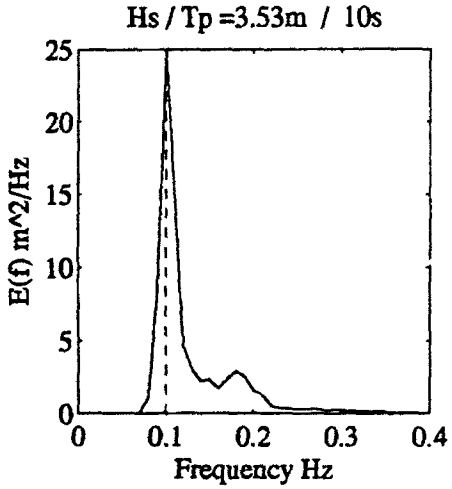
The two-dimensional wave spectra are plotted in polar coordinates with five equally spaced contours between the maximum of $\log[F(f,\ \theta\ )]$ and $\log[F(f,\ \theta\ )] = -1.25$. Each plot presents a directional wave spectrum, its corresponding one-dimensional frequency spectrum, $E(f) = \int F(f,\theta\ )\, d\theta$ and a vector of the prevailing wind direction. The frequency axis ranges from 0 to 0.4 Hz with concentric circles every 0.1 Hz. The top header of the directional wave spectral plot identifies the buoy station, date and time in GMT. The bottom header provides the wind speed and wind direction (from) measured clockwise from north, as well as the mean and peak wave directions (towards). The header of the frequency spectrum provides the significant wave height and the peak period, which is also marked (dashed line) on the plot.

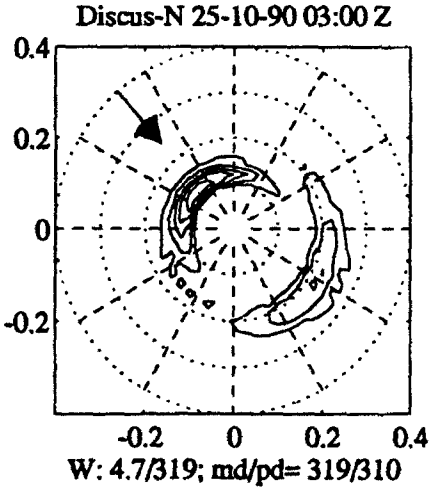
B.1: Discus Buoy "North"

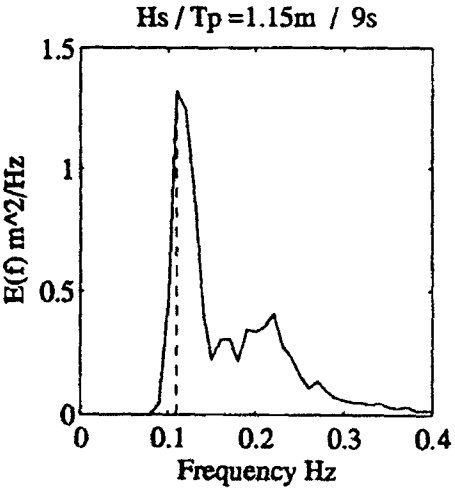

Discus-N 24-10-90 03:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 8.1/243; md/pd= 347/340

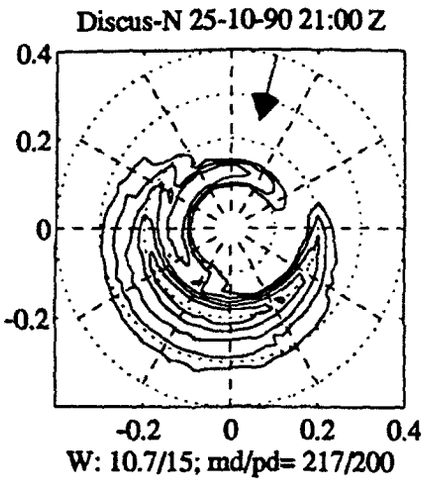

Hs / Tp =3.93m / 10s
25
20
15
10
5
0
E(f) m^2/Hz
0
0.1
0.2
0.3
0.4
Frequency Hz

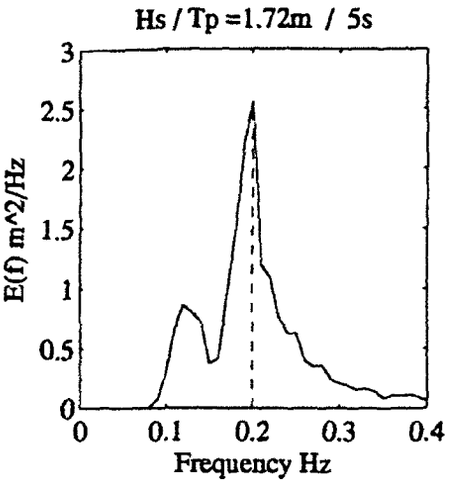

Discus-N 24-10-90 09:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 9.6/271; md/pd= 358/350

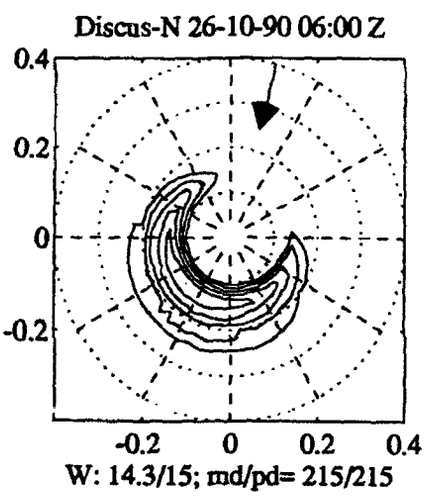

Hs / Tp =3.53m / 10s
25
20
15
10
5
0
E(f) m^2/Hz
0
0.1
0.2
0.3
0.4
Frequency Hz

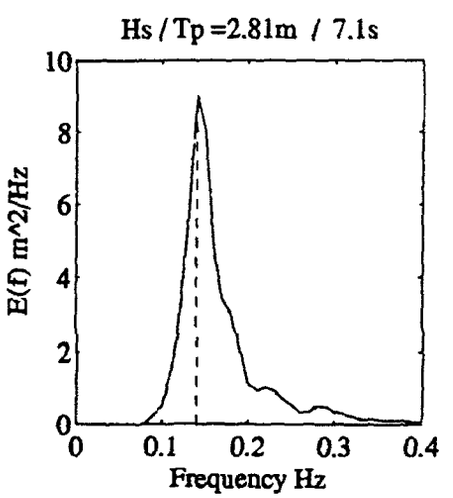

Discus-N 25-10-90 03:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 4.7/319; md/pd= 319/310

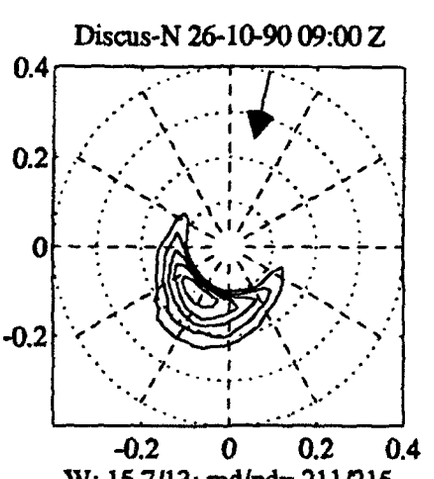

Hs / Tp =1.15m / 9s
1.5
1
0.5
0
E(f) m^2/Hz
0
0.1
0.2
0.3
0.4
Frequency Hz

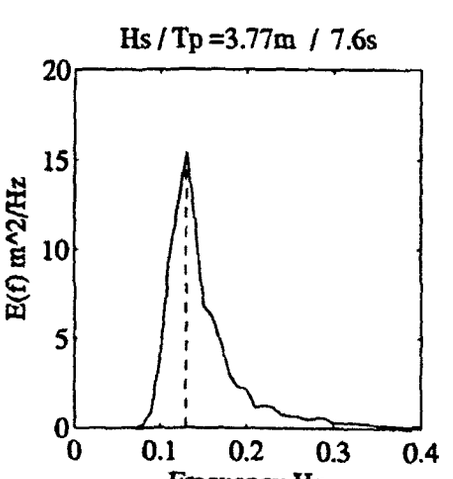

Discus-N 25-10-90 21:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 10.7/15; md/pd= 217/200

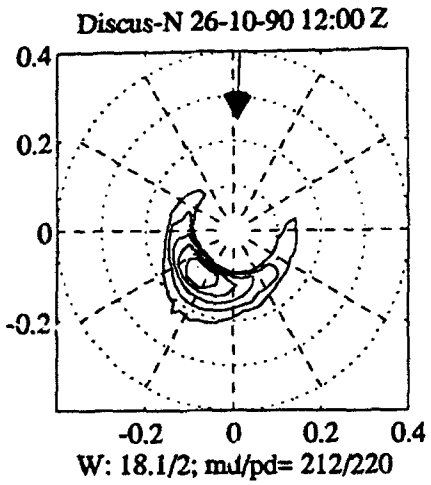

Hs / Tp =1.72m / 5s
E(f) m^2/Hz
3
2.5
2
1.5
1
0.5
0
0
0.1
0.2
0.3
0.4
Frequency Hz

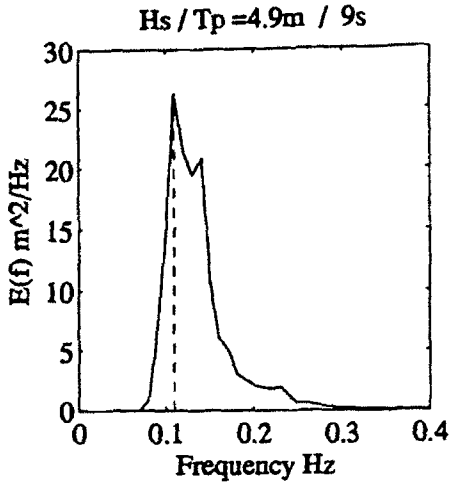

Discus-N 26-10-90 06:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 14.3/15; md/pd= 215/215

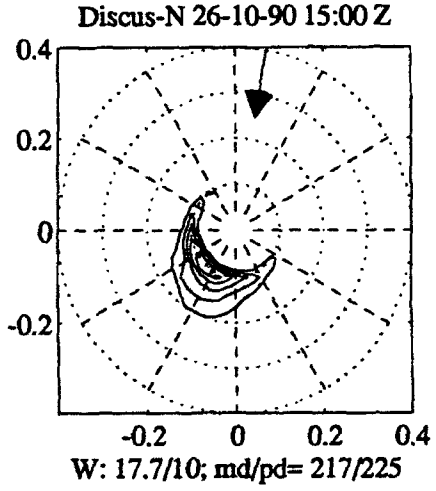

Hs / Tp =2.81m / 7.1s
E(f) m^2/Hz
10
8
6
4
2
0
0
0.1
0.2
0.3
0.4
Frequency Hz

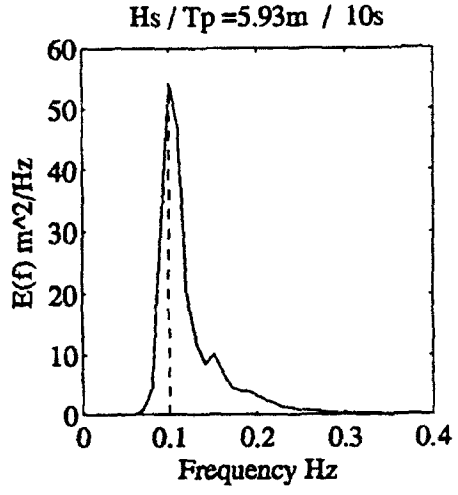

Discus-N 26-10-90 09:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 15.7/13; md/pd= 211/215

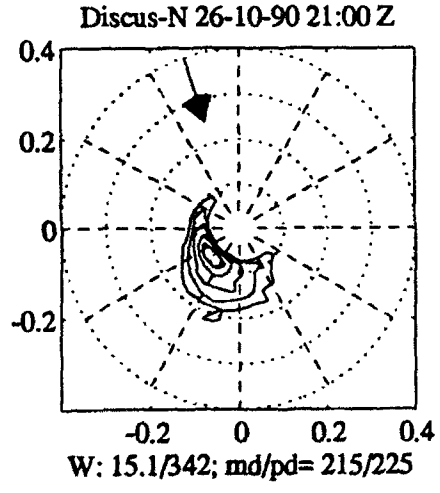

Hs / Tp =3.77m / 7.6s
E(f) m^2/Hz
20
15
10
5
0
0
0.1
0.2
0.3
0.4
Frequency Hz

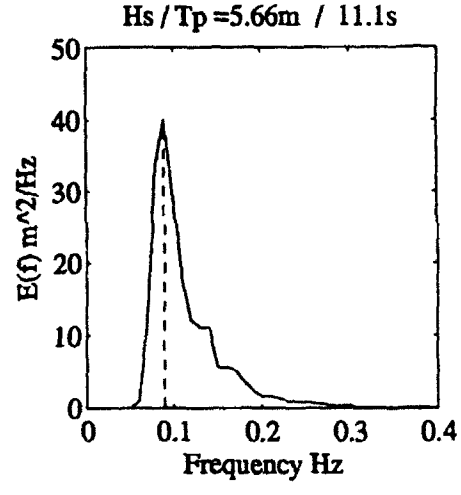

Discus-N 26-10-90 12:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 18.1/2; md/pd= 212/220

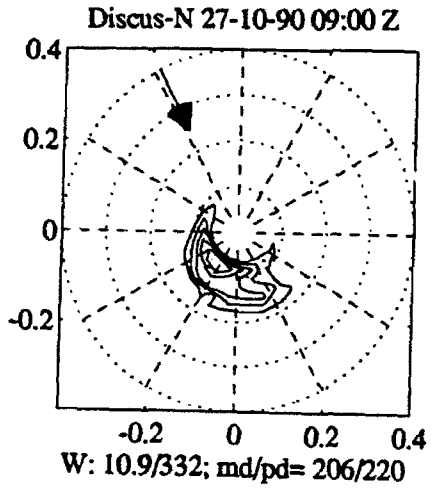

Hs / Tp =4.9m / 9s
E(f) m^2/Hz
30
25
20
15
10
5
0
0
0.1
0.2
0.3
0.4
Frequency Hz

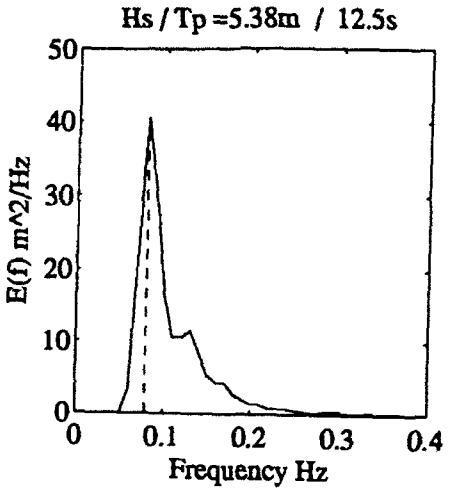

Discus-N 26-10-90 15:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 17.7/10; md/pd= 217/225

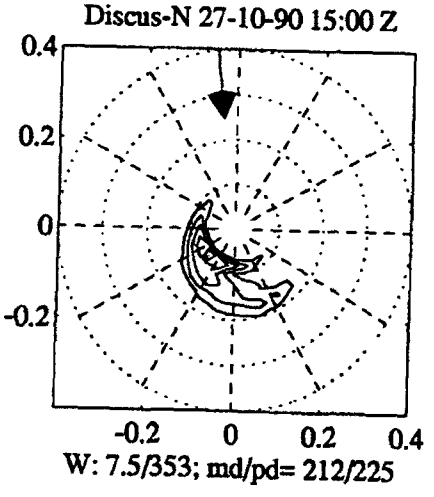

Hs / Tp =5.93m / 10s
E(f) m^2/Hz
60
50
40
30
20
10
0
0
0.1
0.2
0.3
0.4
Frequency Hz

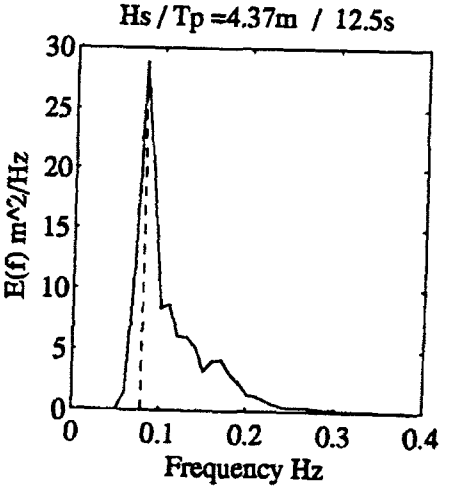

Discus-N 26-10-90 21:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 15.1/342; md/pd= 215/225

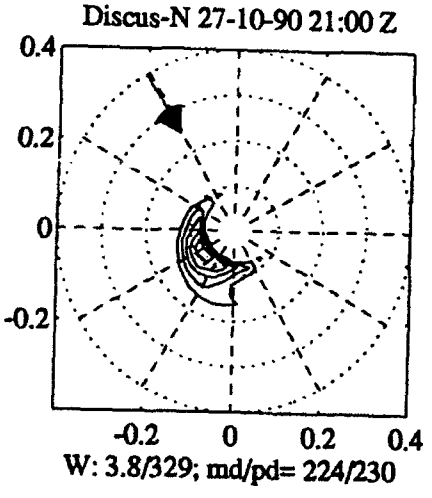

Hs / Tp =5.66m / 11.1s
E(f) m^2/Hz
50
40
30
20
10
0
0
0.1
0.2
0.3
0.4
Frequency Hz

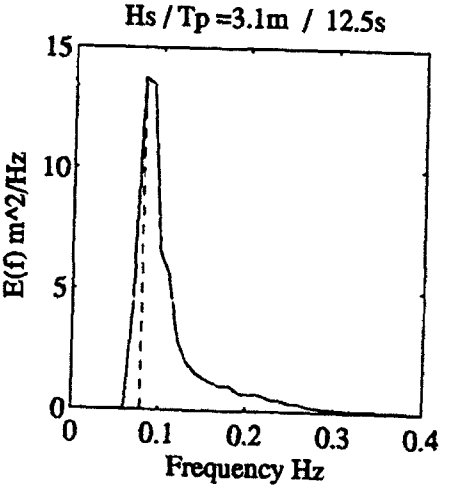

Discus-N 27-10-90 09:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 10.9/332; md/pd= 206/220

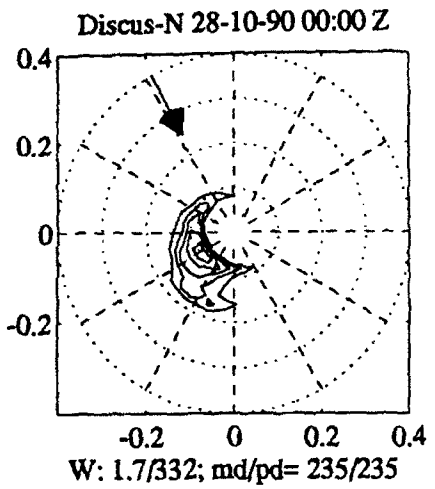

Hs / Tp =5.38m / 12.5s
50
40
30
20
10
0
E(f) m^2/Hz
0
0.1
0.2
0.3
0.4
Frequency Hz

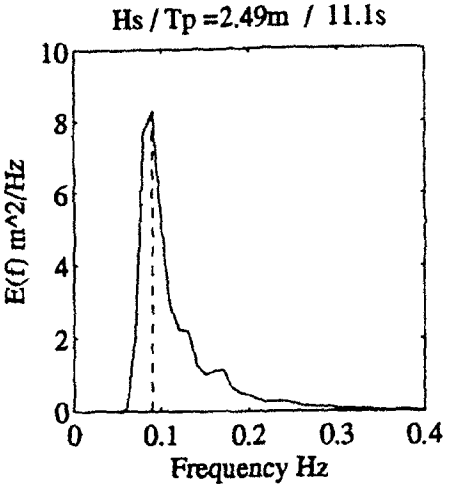

Discus-N 27-10-90 15:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 7.5/353; md/pd= 212/225

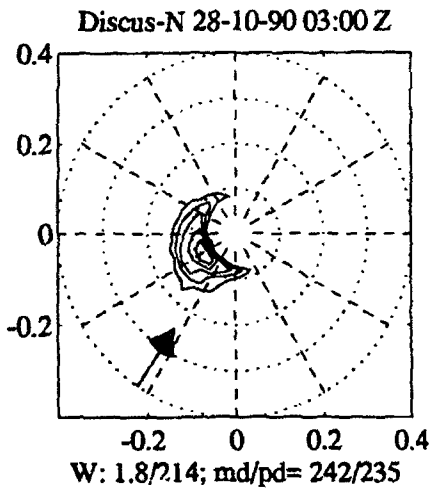

Hs / Tp =4.37m / 12.5s
30
25
20
15
10
5
0
E(f) m^2/Hz
0
0.1
0.2
0.3
0.4
Frequency Hz

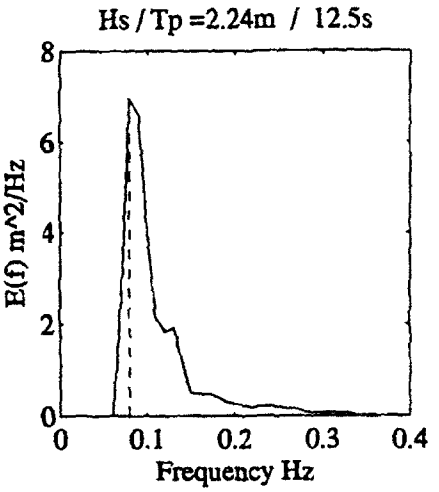

Discus-N 27-10-90 21:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 3.8/329; md/pd= 224/230

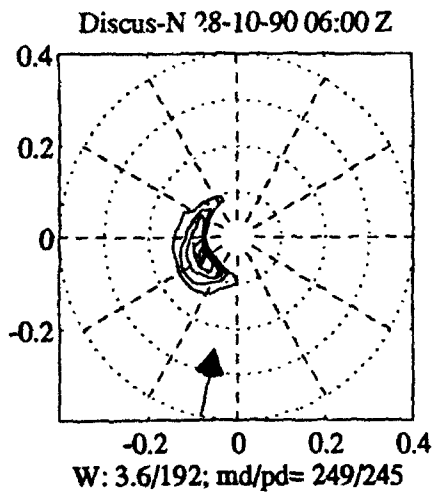

Hs / Tp =3.1m / 12.5s
15
10
5
0
E(f) m^2/Hz
0
0.1
0.2
0.3
0.4
Frequency Hz

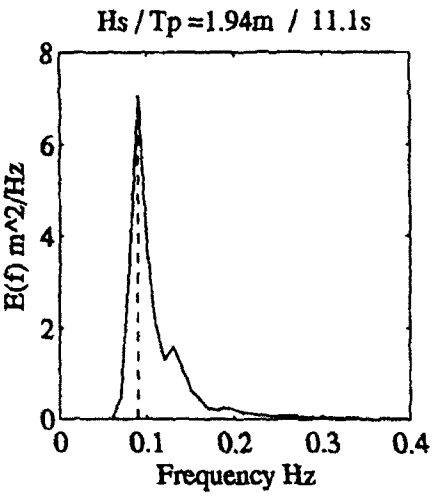

Discus-N 28-10-90 00:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 1.7/332; md/pd= 235/235

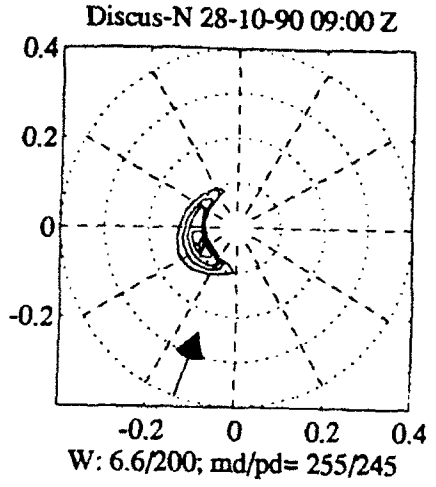

Hs / Tp =2.49m / 11.1s
E(f) m^2/Hz
10
8
6
4
2
0
0
0.1
0.2
0.3
0.4
Frequency Hz

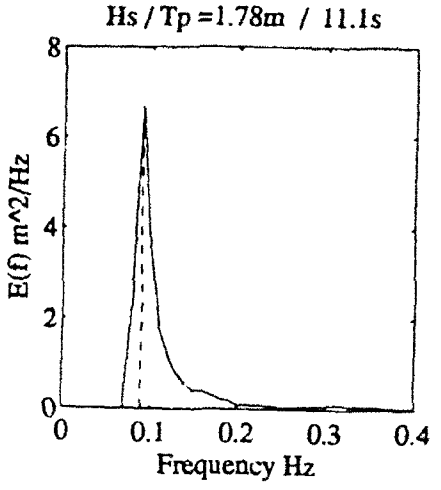

Discus-N 28-10-90 03:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 1.8/214; md/pd= 242/235

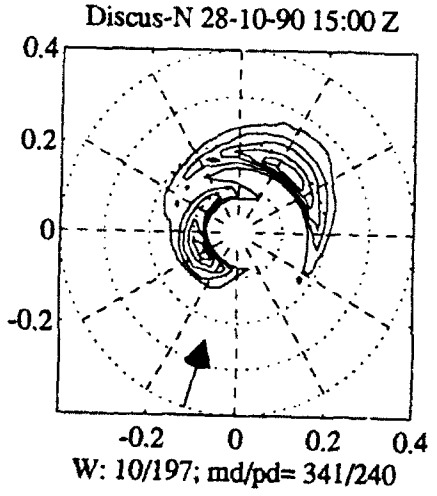

Hs / Tp =2.24m / 12.5s
E(f) m^2/Hz
8
6
4
2
0
0
0.1
0.2
0.3
0.4
Frequency Hz

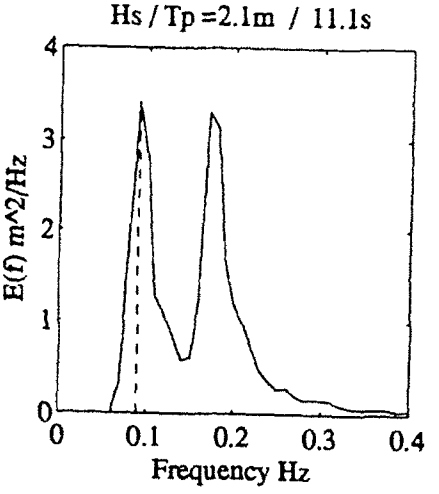

Discus-N 28-10-90 06:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 3.6/192; md/pd= 249/245

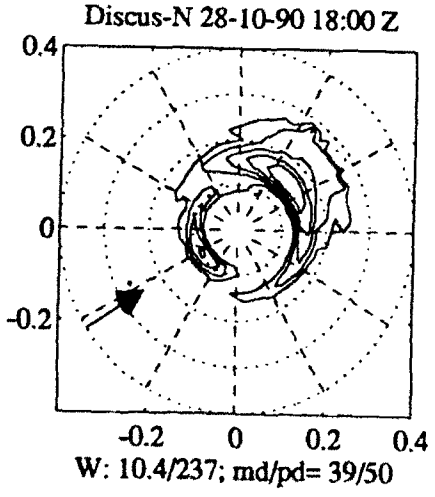

Hs / Tp =1.94m / 11.1s
E(f) m^2/Hz
8
6
4
2
0
0
0.1
0.2
0.3
0.4
Frequency Hz

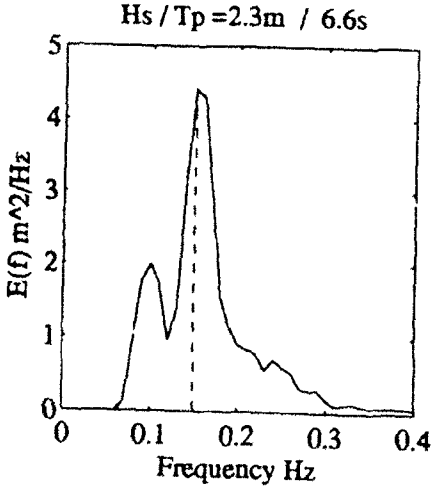

Discus-N 28-10-90 09:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 6.6/200; md/pd= 255/245


Hs / Tp =1.78m / 11.1s
E(f) m^2/Hz
8
6
4
2
0
0
0.1
0.2
0.3
0.4
Frequency Hz

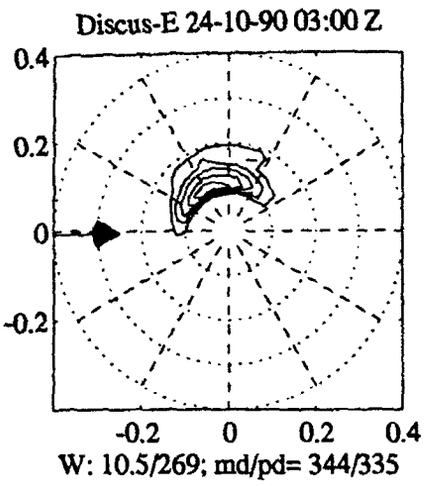

Discus-N 28-10-90 15:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 10/197; md/pd= 341/240

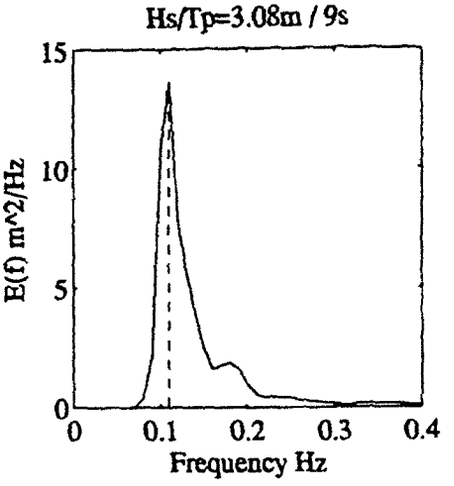

Hs / Tp =2.1m / 11.1s
E(f) m^2/Hz
4
3
2
1
0
0
0.1
0.2
0.3
0.4
Frequency Hz

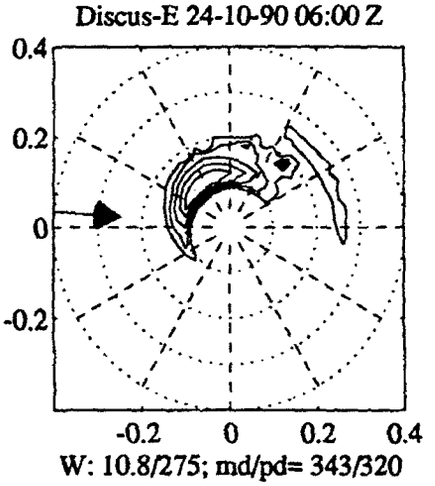

Discus-N 28-10-90 18:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 10.4/237; md/pd= 39/50

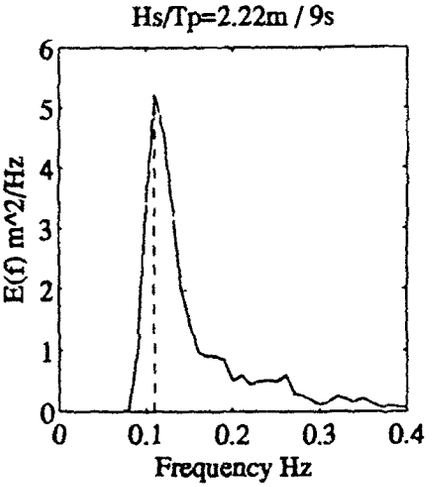

Hs / Tp =2.3m / 6.6s
E(f) m^2/Hz
5
4
3
2
1
0
0
0.1
0.2
0.3
0.4
Frequency Hz

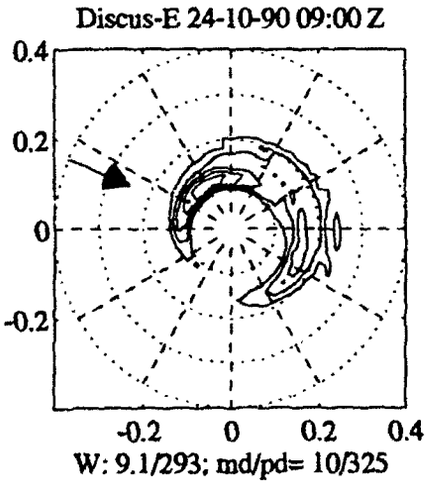
B.2: Discus Buoy "East"

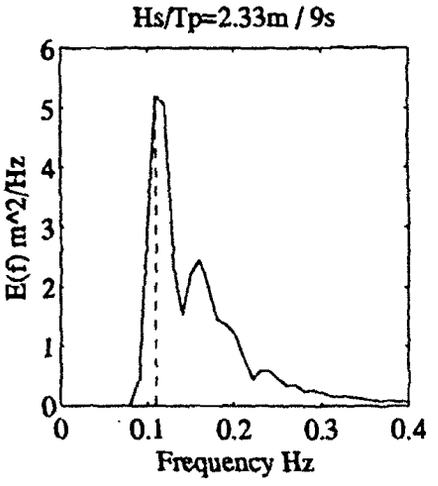

Discus-E 24-10-90 03:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 10.5/269; md/pd= 344/335

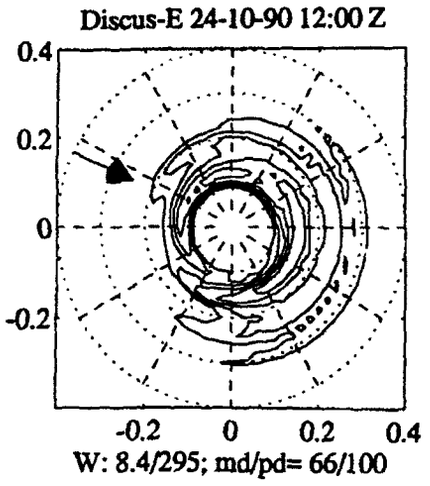

Hs/Tp=3.08m / 9s
15
10
5
0
E(f) m^2/Hz
0
0.1
0.2
0.3
0.4
Frequency Hz

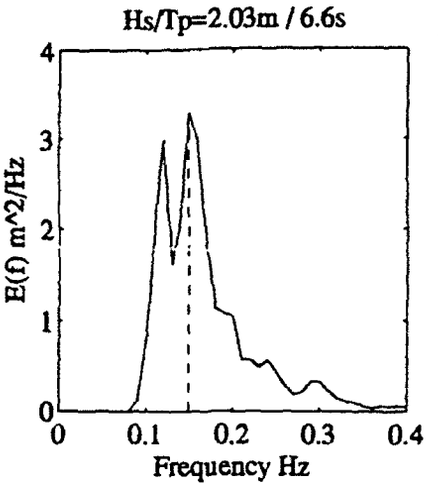

Discus-E 24-10-90 06:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 10.8/275; md/pd= 343/320

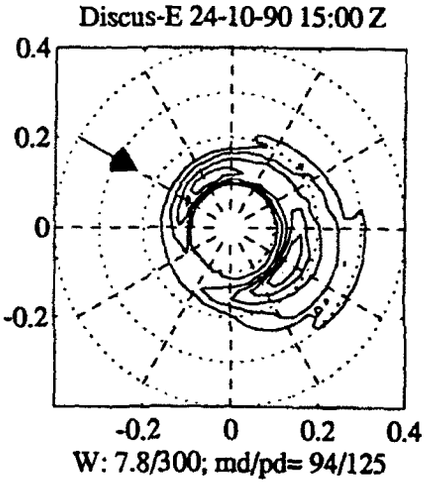

Hs/Tp=2.22m / 9s
6
5
4
3
2
1
0
E(f) m^2/Hz
0
0.1
0.2
0.3
0.4
Frequency Hz

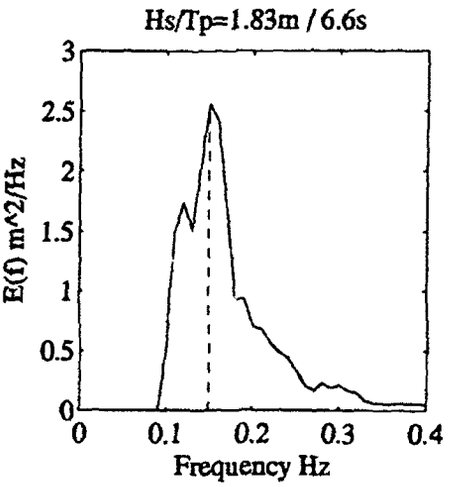

Discus-E 24-10-90 09:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 9.1/293; md/pd= 10/325

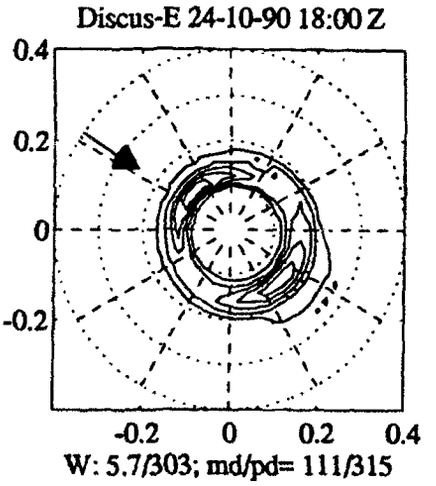

Hs/Tp=2.33m / 9s
6
5
4
3
2
1
0
E(f) m^2/Hz
0
0.1
0.2
0.3
0.4
Frequency Hz

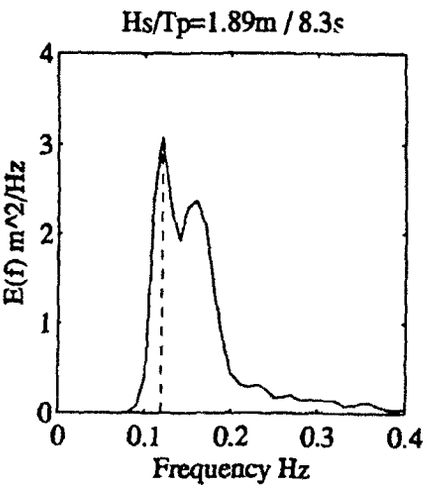

Discus-E 24-10-90 12:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 8.4/295; md/pd= 66/100

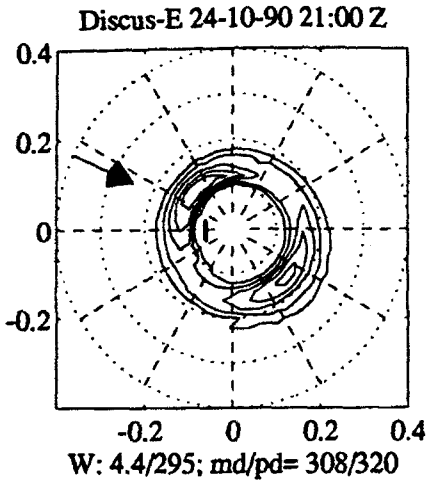

Hs/Tp=2.03m / 6.6s
E(f) m^2/Hz
4
3
2
1
0
0
0.1
0.2
0.3
0.4
Frequency Hz

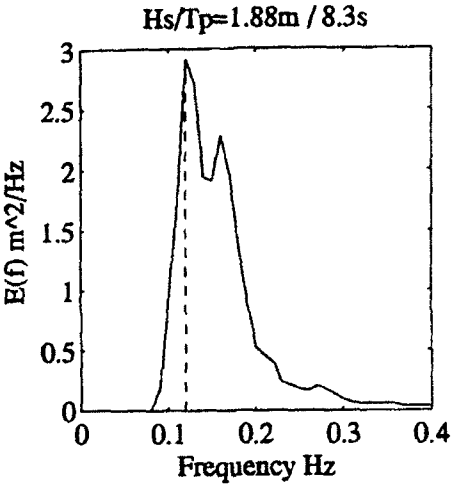

Discus-E 24-10-90 15:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 7.8/300; md/pd= 94/125

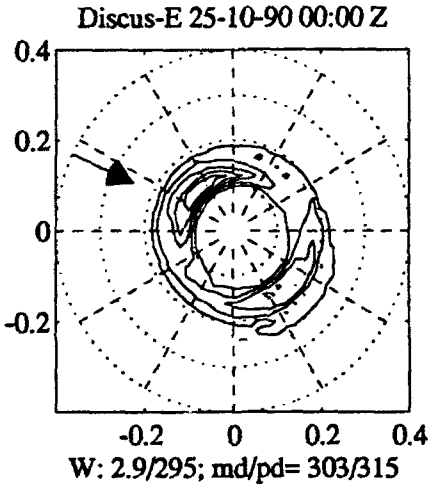

Hs/Tp=1.83m / 6.6s
E(f) m^2/Hz
3
2.5
2
1.5
1
0.5
0
0
0.1
0.2
0.3
0.4
Frequency Hz

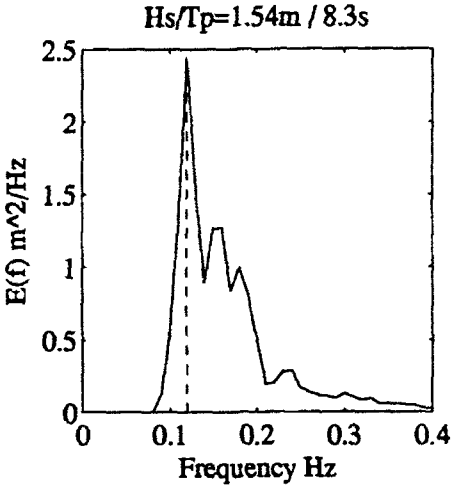

Discus-E 24-10-90 18:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 5.7/303; md/pd= 111/315

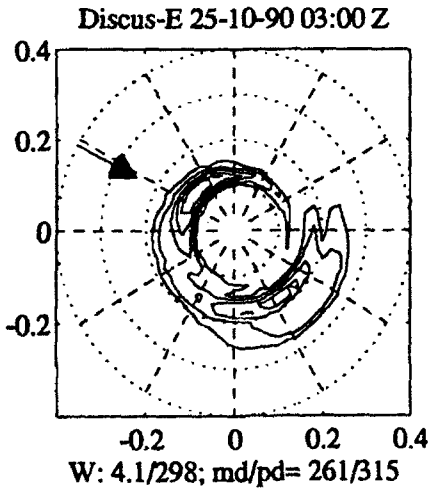

Hs/Tp=1.89m / 8.3s
E(f) m^2/Hz
4
3
2
1
0
0
0.1
0.2
0.3
0.4
Frequency Hz

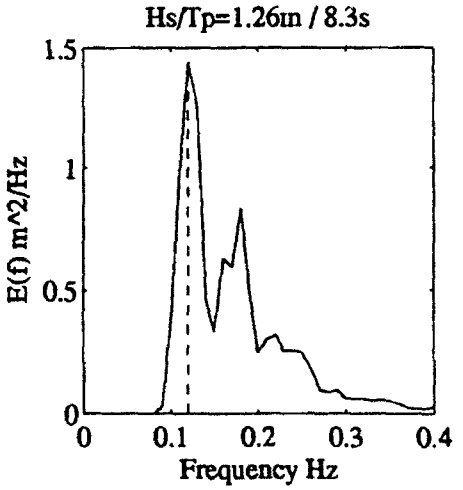

Discus-E 24-10-90 21:00 Z
0.4
0.2
0
-0.2
E
-0.2 0 0.2 0.4
W: 4.4/295; md/pd= 308/320

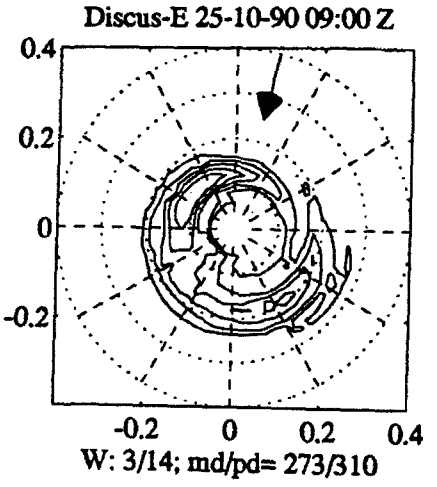

Hs/Tp=1.88m / 8.3s
E(f) m^2/Hz
3
2.5
2
1.5
1
0.5
0
0 0.1 0.2 0.3 0.4
Frequency Hz

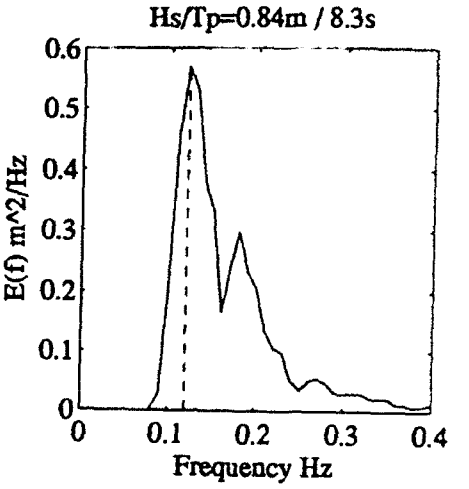

Discus-E 25-10-90 00:00 Z
0.4
0.2
0
-0.2
-0.2 0 0.2 0.4
W: 2.9/295; md/pd= 303/315

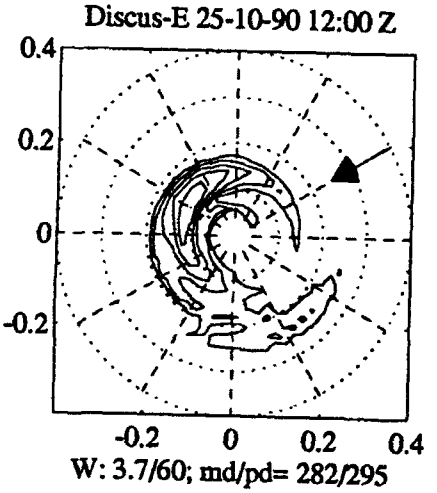

Hs/Tp=1.54m / 8.3s
E(f) m^2/Hz
2.5
2
1.5
1
0.5
0
0 0.1 0.2 0.3 0.4
Frequency Hz

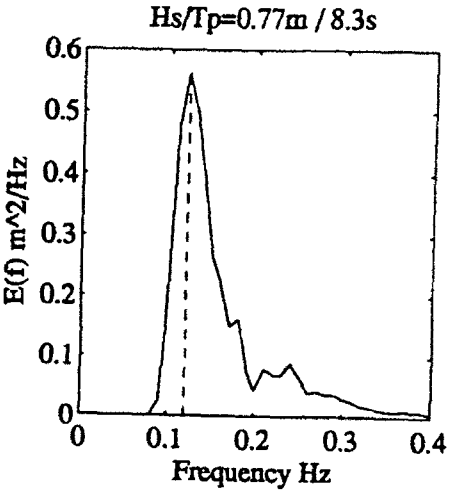

Discus-E 25-10-90 03:00 Z
0.4
0.2
0
-0.2
-0.2 0 0.2 0.4
W: 4.1/298; md/pd= 261/315

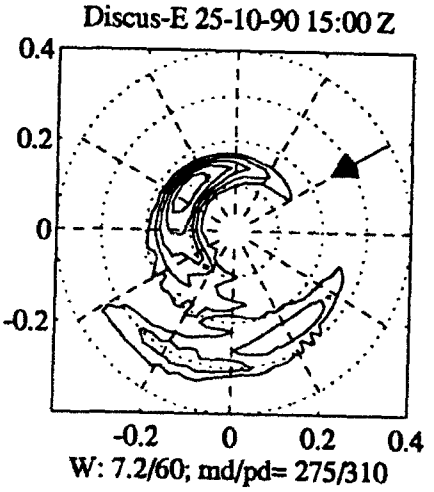

Hs/Tp=1.26m / 8.3s
E(f) m^2/Hz
1.5
1
0.5
0
0 0.1 0.2 0.3 0.4
Frequency Hz

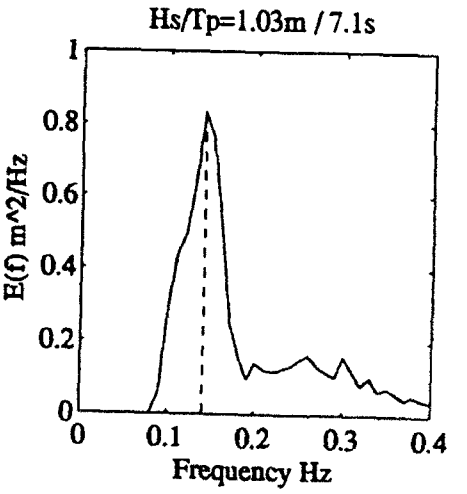

Discus-E 25-10-90 09:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 3/14; md/pd= 273/310

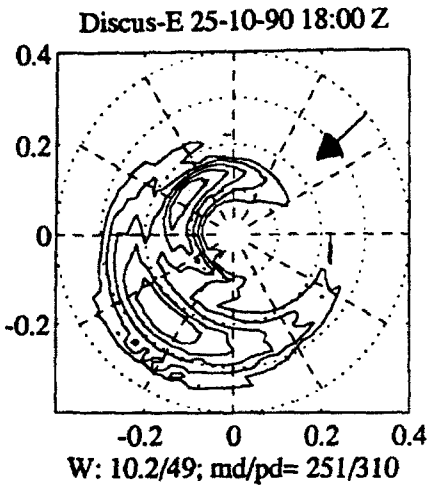

Hs/Tp=0.84m / 8.3s
0.6
0.5
0.4
0.3
0.2
0.1
0
E(f) m^2/Hz
0
0.1
0.2
0.3
0.4
Frequency Hz

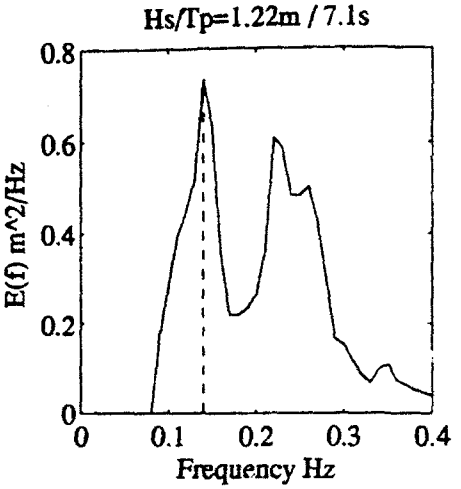

Discus-E 25-10-90 12:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 3.7/60; md/pd= 282/295

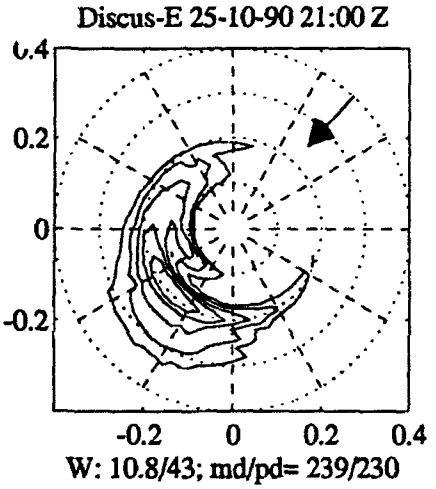

Hs/Tp=0.77m / 8.3s
0.6
0.5
0.4
0.3
0.2
0.1
0
E(f) m^2/Hz
0
0.1
0.2
0.3
0.4
Frequency Hz

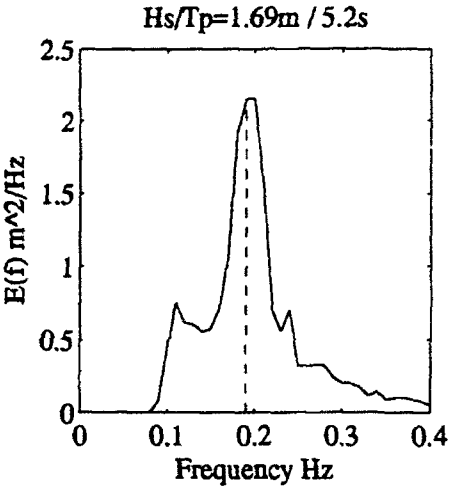

Discus-E 25-10-90 15:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 7.2/60; md/pd= 275/310

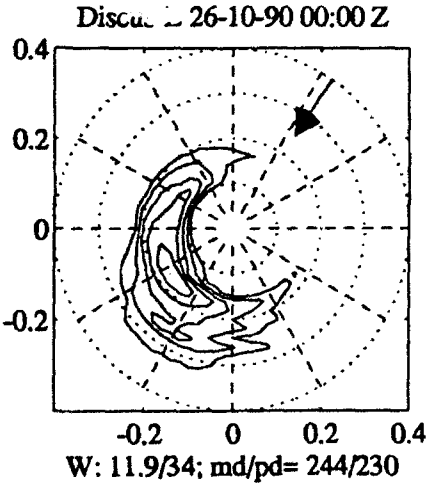

Hs/Tp=1.03m / 7.1s
1
0.8
0.6
0.4
0.2
0
E(f) m^2/Hz
0
0.1
0.2
0.3
0.4
Frequency Hz

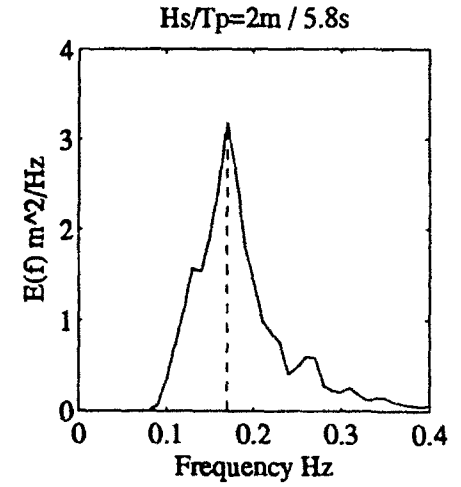

Discus-E 25-10-90 18:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 10.2/49; md/pd= 251/310

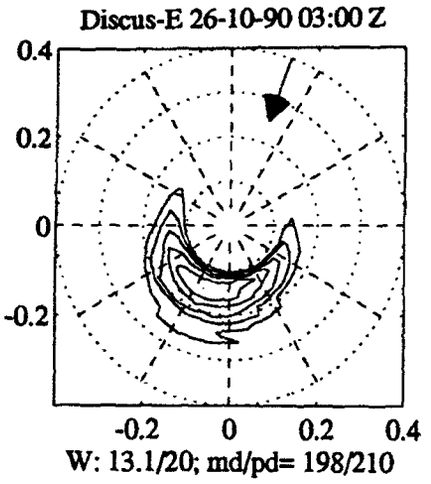

Hs/Tp=1.22m / 7.1s
0.8
0.6
0.4
0.2
0
E(f) m^2/Hz
0
0.1
0.2
0.3
0.4
Frequency Hz

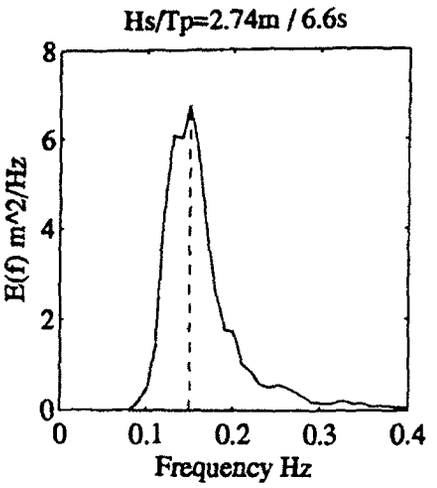

Discus-E 25-10-90 21:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 10.8/43; md/pd= 239/230

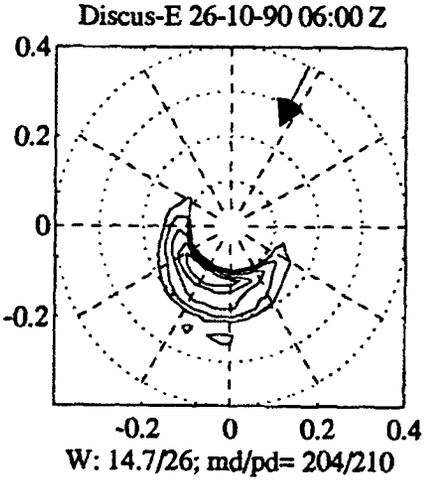

Hs/Tp=1.69m / 5.2s
2.5
2
1.5
1
0.5
0
E(f) m^2/Hz
0
0.1
0.2
0.3
0.4
Frequency Hz

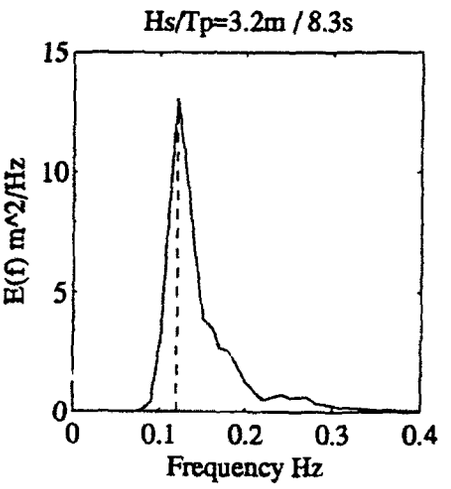

Discus-E 26-10-90 00:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 11.9/34; md/pd= 244/230

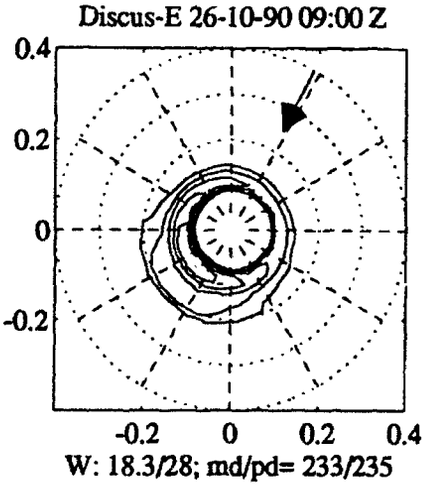

Hs/Tp=2m / 5.8s
4
3
2
1
0
E(f) m^2/Hz
0
0.1
0.2
0.3
0.4
Frequency Hz

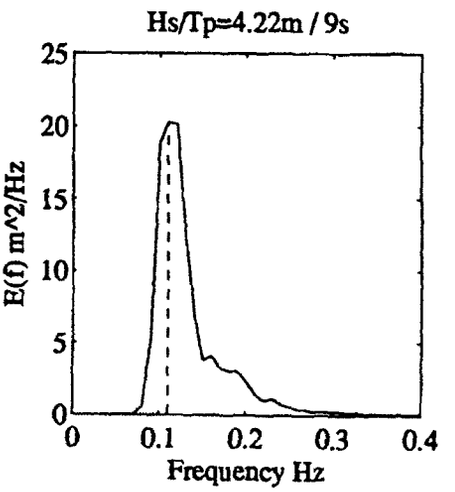

Discus-E 26-10-90 03:00 Z
0.4
0.2
0
-0.2
-0.2 0 0.2 0.4
W: 13.1/20; md/pd= 198/210

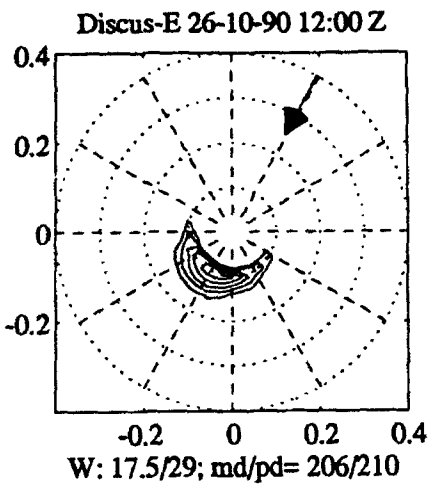

Hs/Tp=2.74m / 6.6s
E(f) m^2/Hz
8
6
4
2
0
0 0.1 0.2 0.3 0.4
Frequency Hz

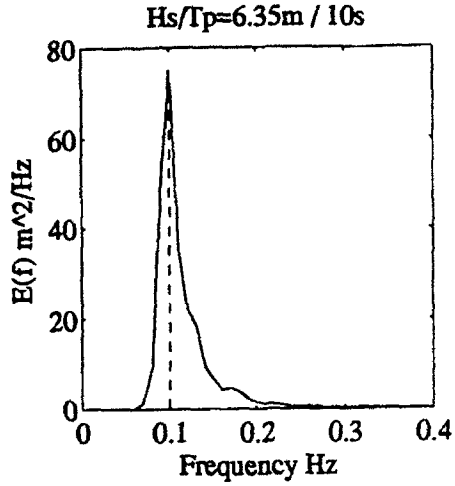

Discus-E 26-10-90 06:00 Z
0.4
0.2
0
-0.2
-0.2 0 0.2 0.4
W: 14.7/26; md/pd= 204/210

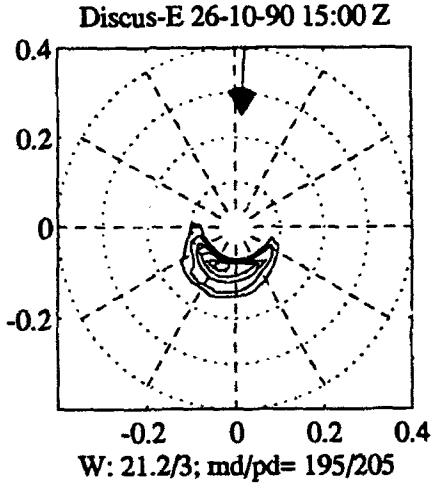

Hs/Tp=3.2m / 8.3s
E(f) m^2/Hz
15
10
5
0
0 0.1 0.2 0.3 0.4
Frequency Hz

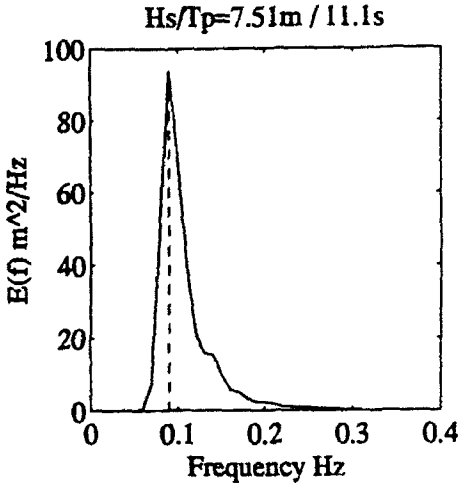

Discus-E 26-10-90 09:00 Z
0.4
0.2
0
-0.2
-0.2 0 0.2 0.4
W: 18.3/28; md/pd= 233/235

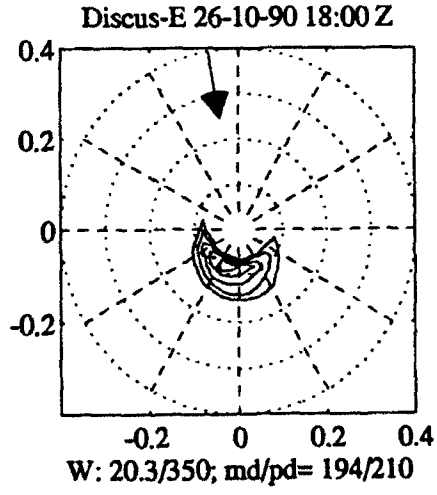

Hs/Tp=4.22m / 9s
E(f) m^2/Hz
25
20
15
10
5
0
0 0.1 0.2 0.3 0.4
Frequency Hz

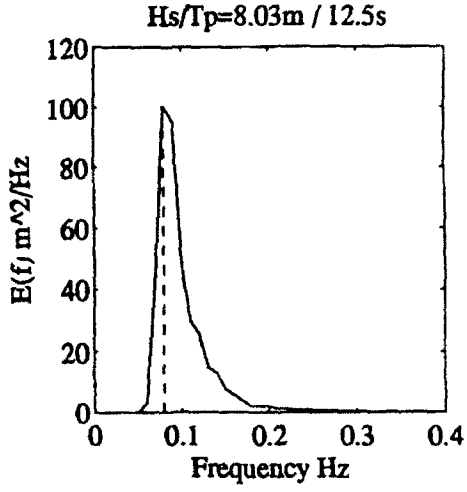

Discus-E 26-10-90 12:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 17.5/29; md/pd= 206/210

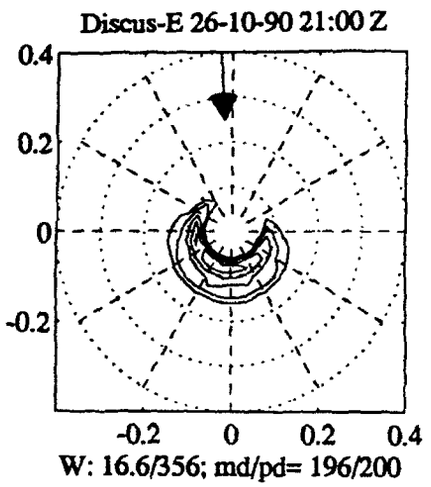

Hs/Tp=6.35m / 10s
E(f) m^2/Hz
80
60
40
20
0
0
0.1
0.2
0.3
0.4
Frequency Hz

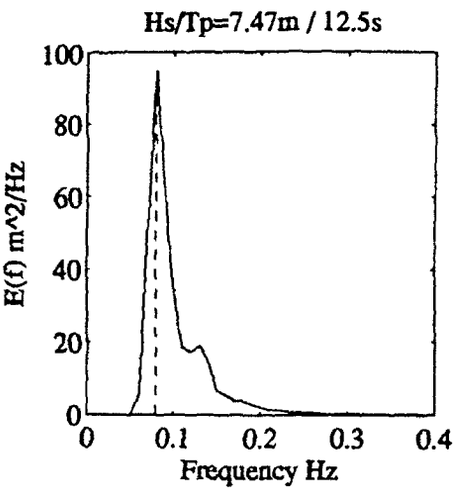

Discus-E 26-10-90 15:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 21.2/3; md/pd= 195/205

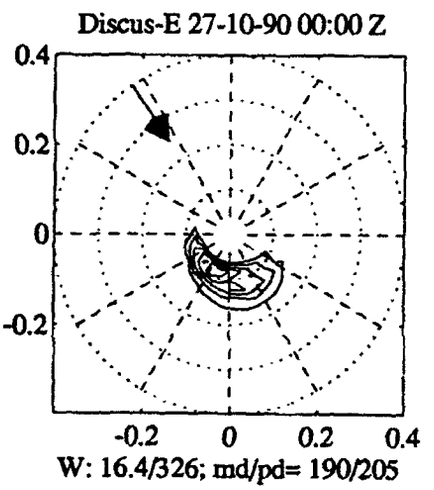

Hs/Tp=7.51m / 11.1s
E(f) m^2/Hz
100
80
60
40
20
0
0
0.1
0.2
0.3
0.4
Frequency Hz

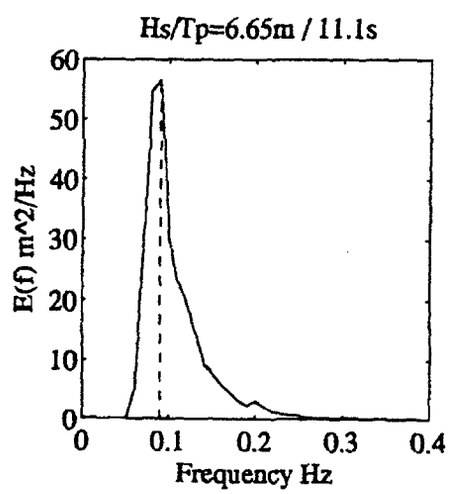

Discus-E 26-10-90 18:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 20.3/350; md/pd= 194/210

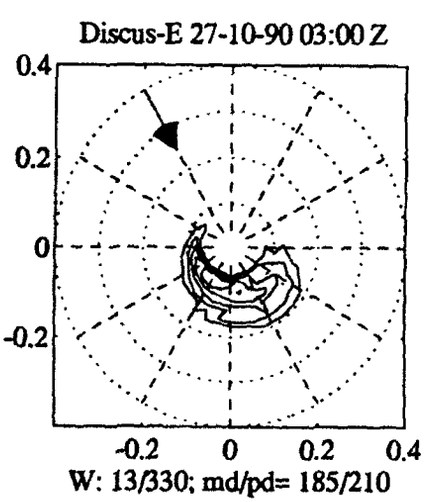

Hs/Tp=8.03m / 12.5s
E(f) m^2/Hz
120
100
80
60
40
20
0
0
0.1
0.2
0.3
0.4
Frequency Hz

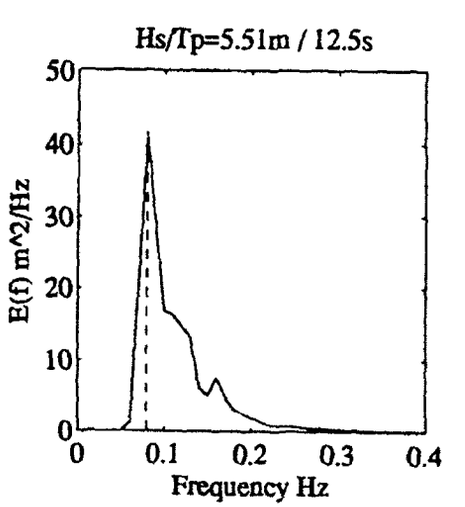

Discus-E 26-10-90 21:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 16.6/356; md/pd= 196/200

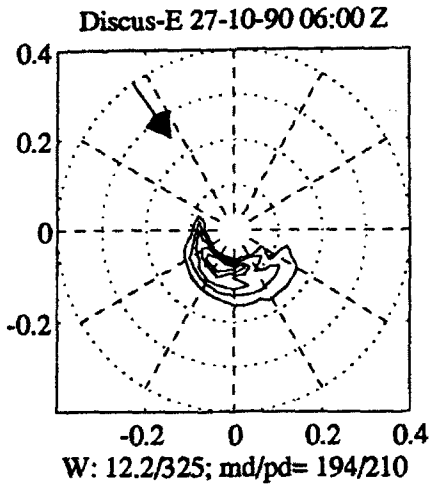

Hs/Tp=7.47m / 12.5s
E(f) m^2/Hz
100
80
60
40
20
0
0
0.1
0.2
0.3
0.4
Frequency Hz

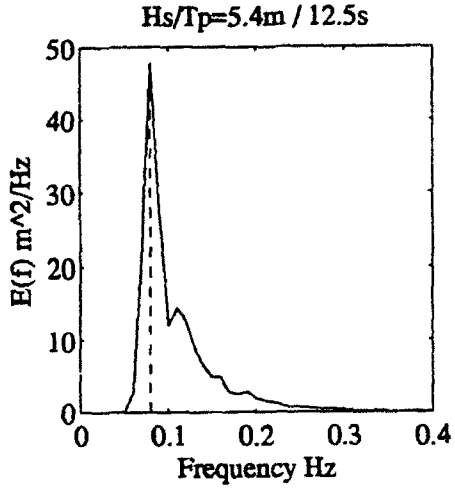

Discus-E 27-10-90 00:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 16.4/326; md/pd= 190/205

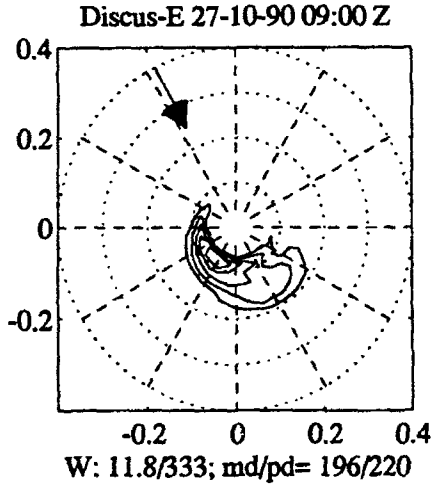

Hs/Tp=6.65m / 11.1s
E(f) m^2/Hz
60
50
40
30
20
10
0
0
0.1
0.2
0.3
0.4
Frequency Hz

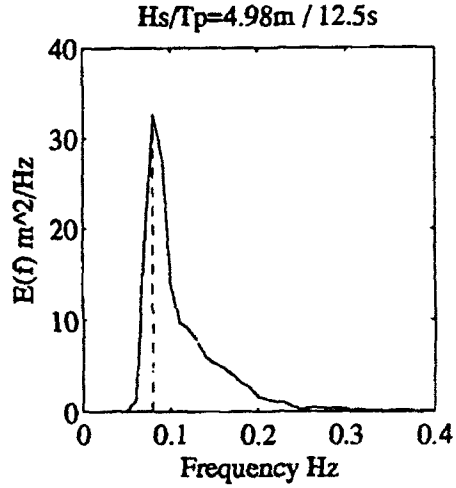

Discus-E 27-10-90 03:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 13/330; md/pd= 185/210

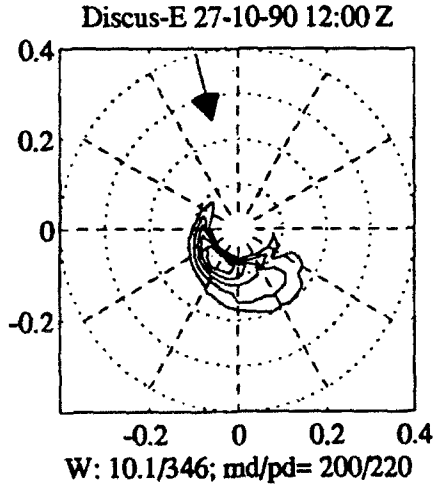

Hs/Tp=5.51m / 12.5s
E(f) m^2/Hz
50
40
30
20
10
0
0
0.1
0.2
0.3
0.4
Frequency Hz

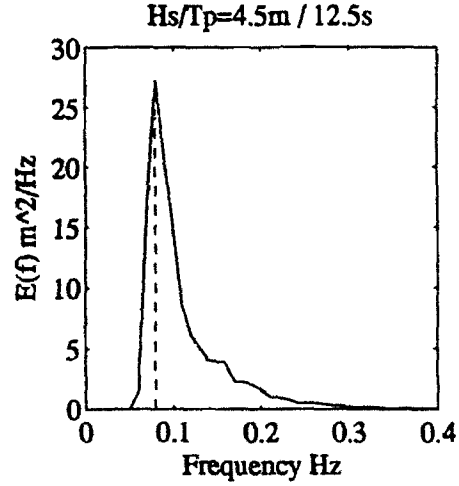

Discus-E 27-10-90 06:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 12.2/325; md/pd= 194/210

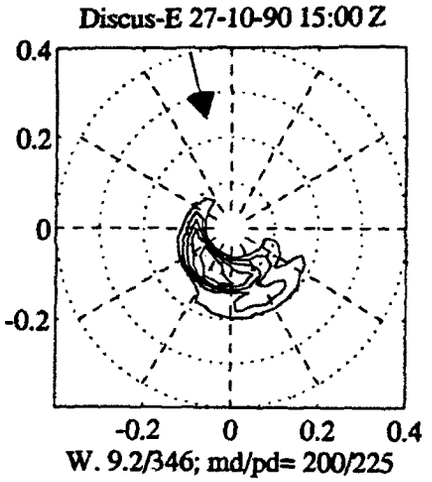

Hs/Tp=5.4m / 12.5s
E(f) m^2/Hz
50
40
30
20
10
0
0
0.1
0.2
0.3
0.4
Frequency Hz

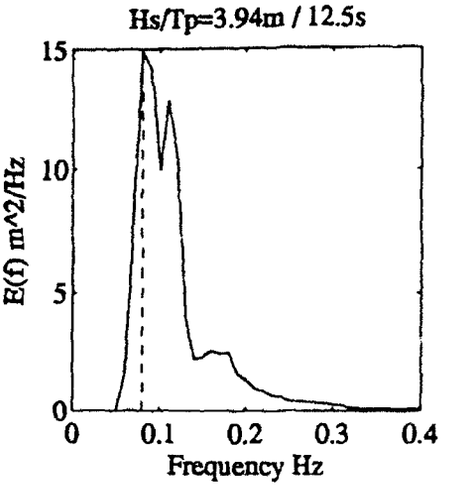

Discus-E 27-10-90 09:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 11.8/333; md/pd= 196/220

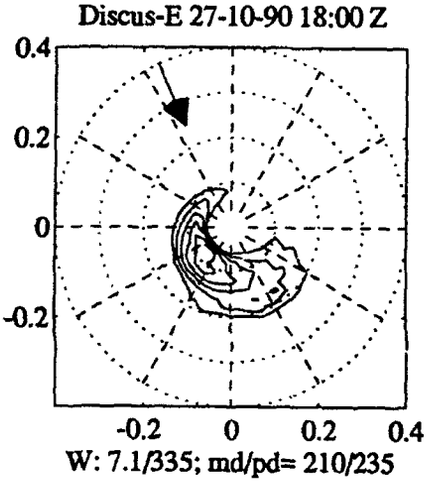

Hs/Tp=4.98m / 12.5s
E(f) m^2/Hz
40
30
20
10
0
0
0.1
0.2
0.3
0.4
Frequency Hz

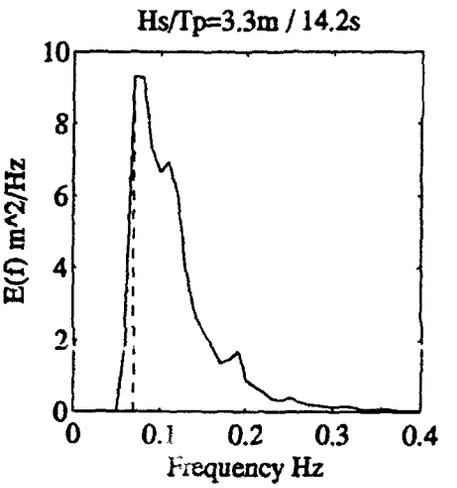

Discus-E 27-10-90 12:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 10.1/346; md/pd= 200/220

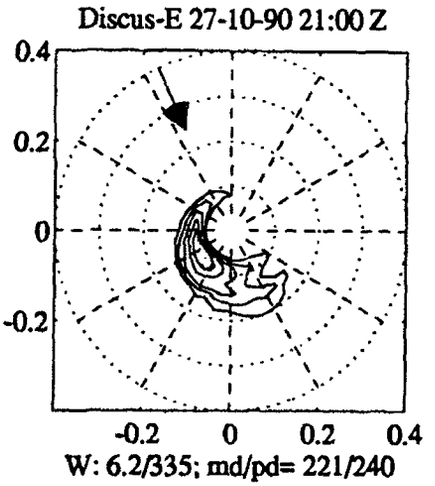

Hs/Tp=4.5m / 12.5s
E(f) m^2/Hz
30
25
20
15
10
5
0
0
0.1
0.2
0.3
0.4
Frequency Hz

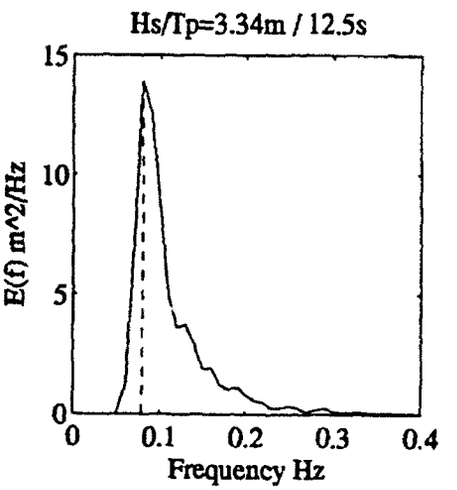

Discus-E 27-10-90 15:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W. 9.2/346; md/pd= 200/225

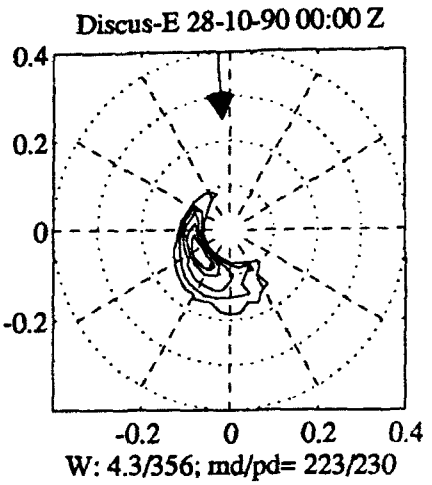

Hs/Tp=3.94m / 12.5s
15
10
5
0
E(f) m^2/Hz
0
0.1
0.2
0.3
0.4
Frequency Hz

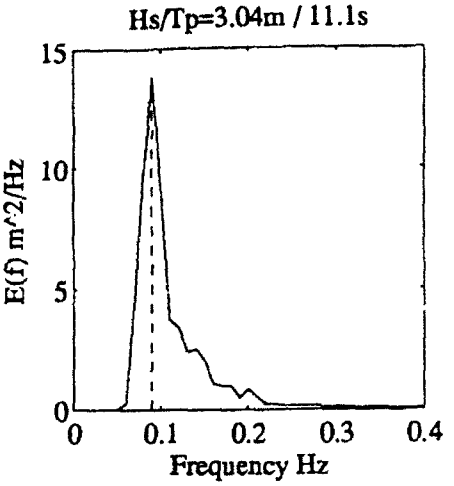

Discus-E 27-10-90 18:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 7.1/335; md/pd= 210/235

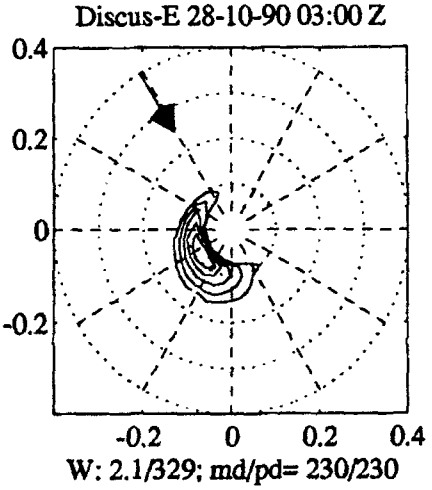

Hs/Tp=3.3m / 14.2s
10
8
6
4
2
0
E(f) m^2/Hz
0
0.1
0.2
0.3
0.4
Frequency Hz

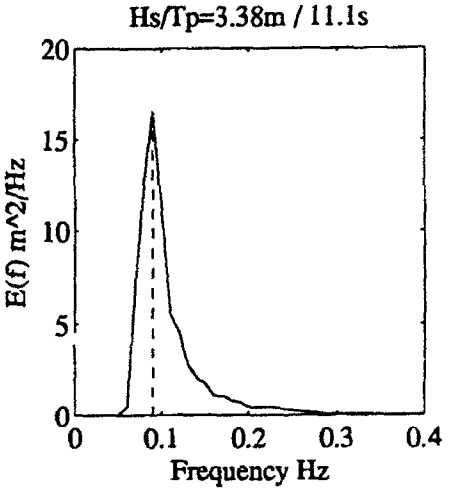

Discus-E 27-10-90 21:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 6.2/335; md/pd= 221/240

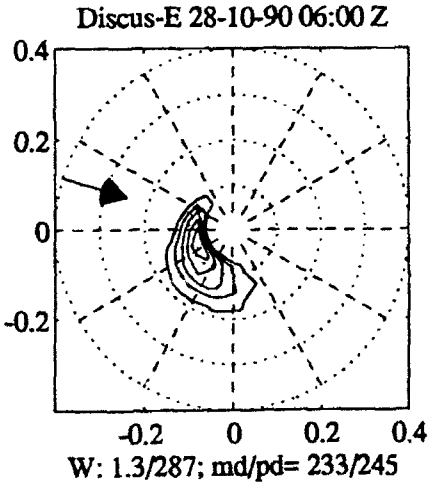

Hs/Tp=3.34m / 12.5s
15
10
5
0
E(f) m^2/Hz
0
0.1
0.2
0.3
0.4
Frequency Hz

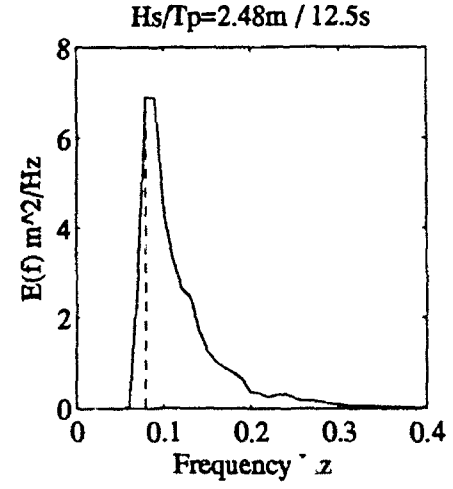

Discus-E 28-10-90 00:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 4.3/356; md/pd= 223/230

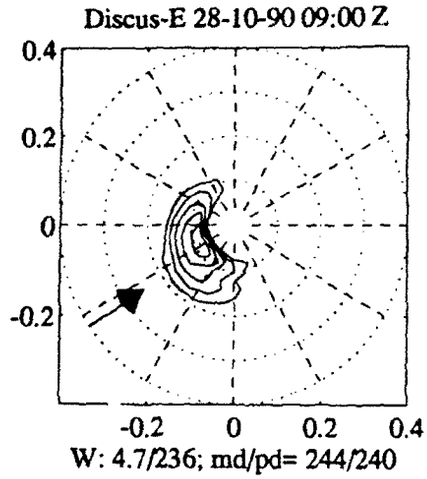

Hs/Tp=3.04m / 11.1s
15
10
5
0
E(f) m^2/Hz
0
0.1
0.2
0.3
0.4
Frequency Hz

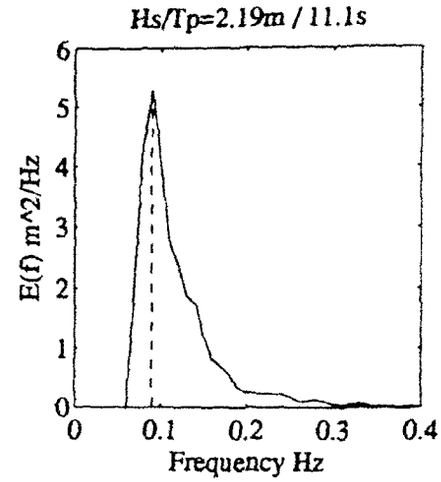

Discus-E 28-10-90 03:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 2.1/329; md/pd= 230/230

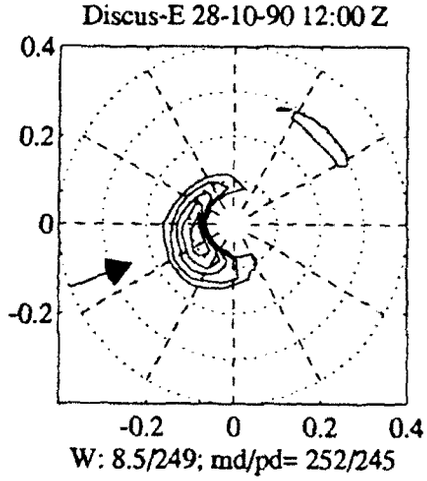

Hs/Tp=3.38m / 11.1s
20
15
10
5
0
E(f) m^2/Hz
0
0.1
0.2
0.3
0.4
Frequency Hz

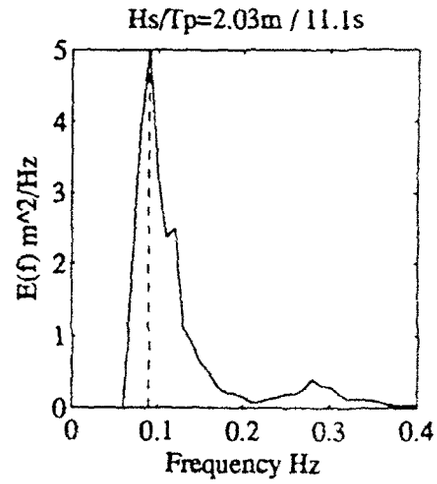

Discus-E 28-10-90 06:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 1.3/287; md/pd= 233/245

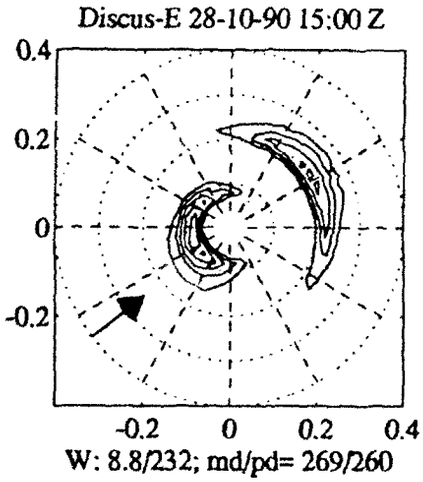

Hs/Tp=2.48m / 12.5s
8
6
4
2
0
E(f) m^2/Hz
0
0.1
0.2
0.3
0.4
Frequency Hz

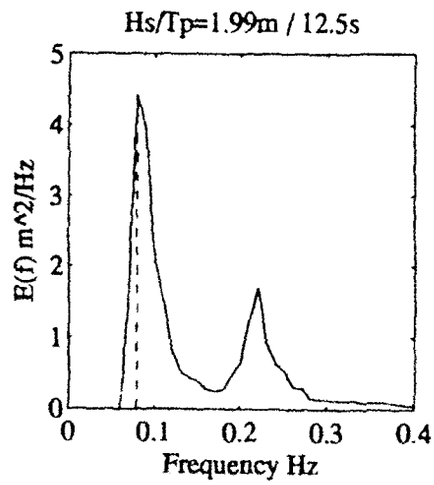

Discus-E 28-10-90 09:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 4.7/236; md/pd= 244/240

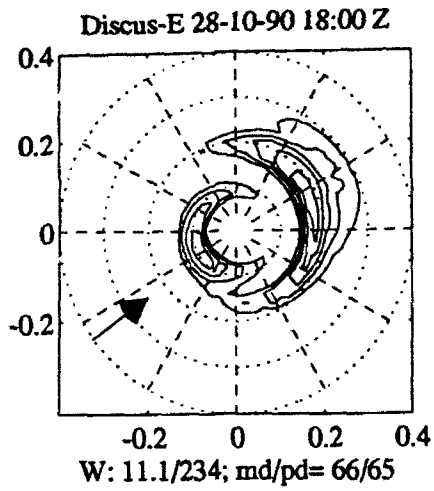

Hs/Tp=2.19m / 11.1s
E(f) m^2/Hz
0
1
2
3
4
5
6
0
0.1
0.2
0.3
0.4
Frequency Hz

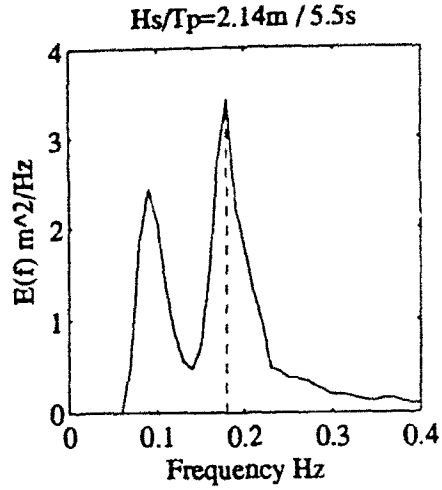

Discus-E 28-10-90 12:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 8.5/249; md/pd= 252/245

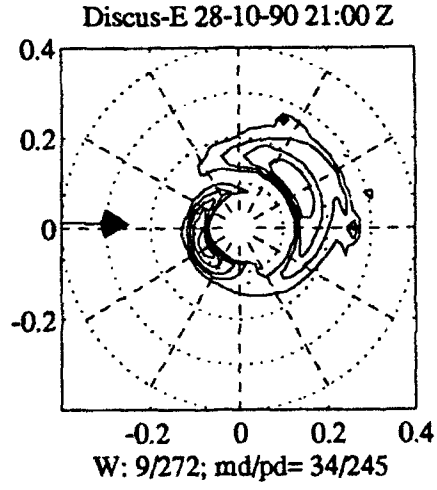

Hs/Tp=2.03m / 11.1s
E(f) m^2/Hz
0
1
2
3
4
5
0
0.1
0.2
0.3
0.4
Frequency Hz

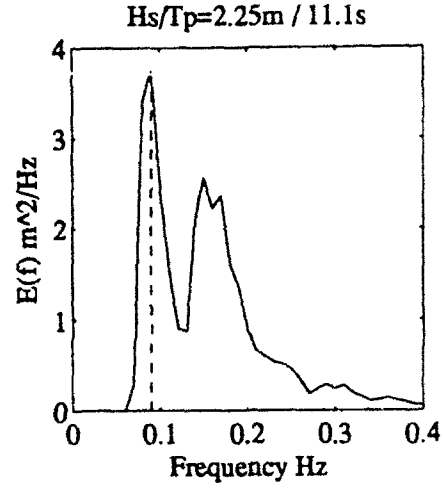

Discus-E 28-10-90 15:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 8.8/232; md/pd= 269/260

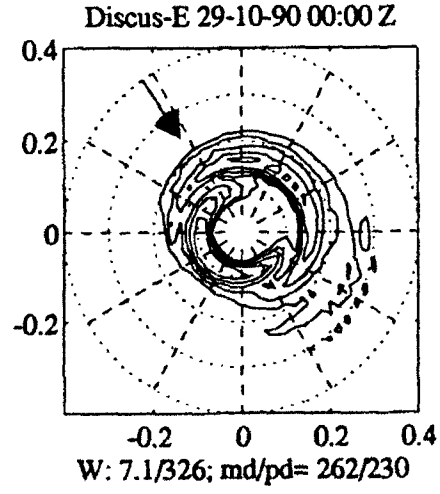

Hs/Tp=1.99m / 12.5s
E(f) m^2/Hz
0
1
2
3
4
5
0
0.1
0.2
0.3
0.4
Frequency Hz

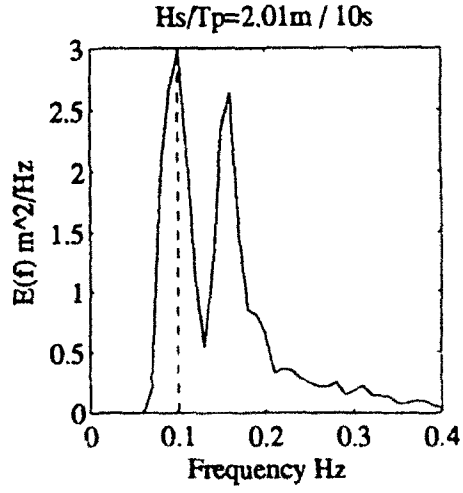

Discus-E 28-10-90 18:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 11.1/234; md/pd= 66/65


Hs/Tp=2.14m / 5.5s
E(f) m^2/Hz
0
1
2
3
4
0
0.1
0.2
0.3
0.4
Frequency Hz

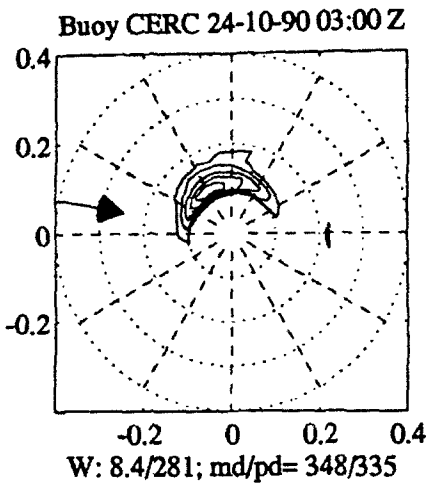

Discus-E 28-10-90 21:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 9/272; md/pd= 34/245

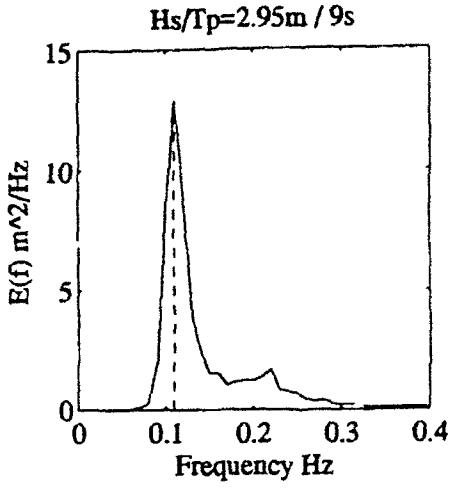

Hs/Tp=2.25m / 11.1s
E(f) m^2/Hz
0
1
2
3
4
0
0.1
0.2
0.3
0.4
Frequency Hz

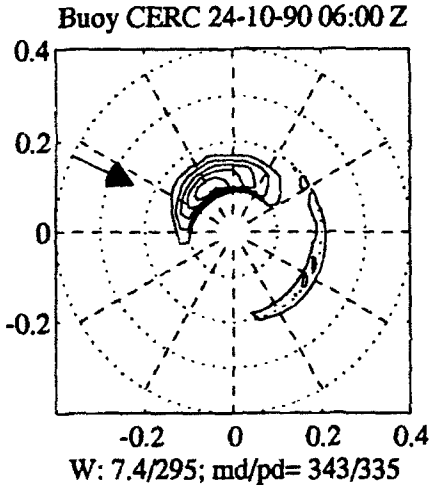

Discus-E 29-10-90 00:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 7.1/326; md/pd= 262/230

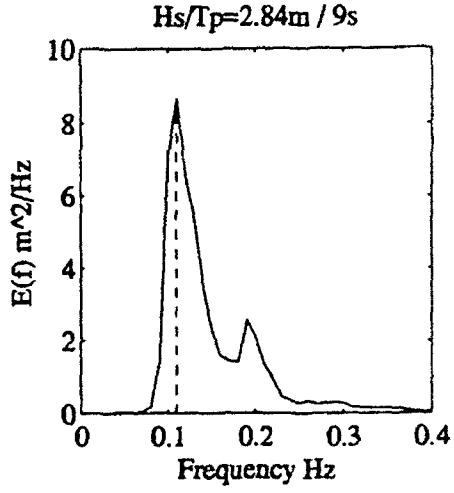

Hs/Tp=2.01m / 10s
E(f) m^2/Hz
0
0.5
1
1.5
2
2.5
3
0
0.1
0.2
0.3
0.4
Frequency Hz

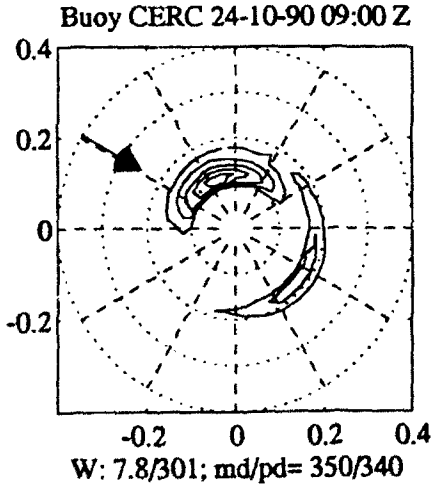
B.3: Discus Buoy "CERC"

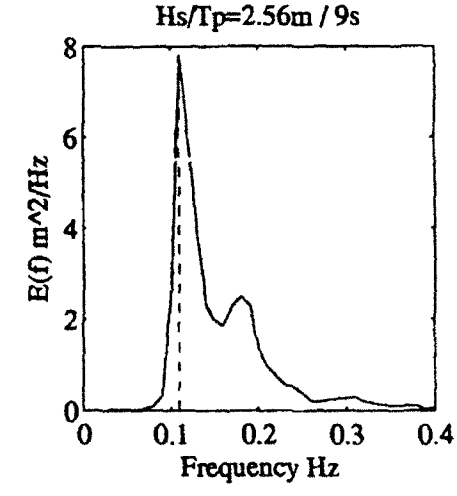

Buoy CERC 24-10-90 03:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 8.4/281; md/pd= 348/335

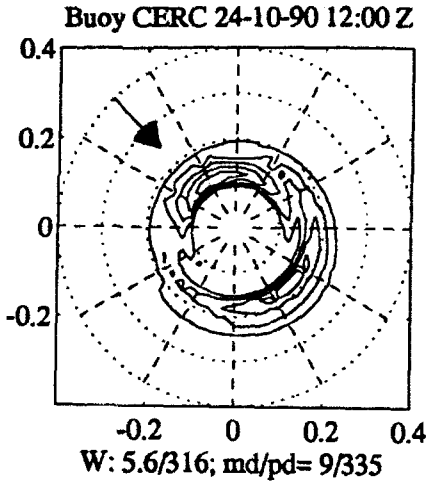

Hs/Tp=2.95m / 9s
15
10
5
0
E(f) m^2/Hz
0
0.1
0.2
0.3
0.4
Frequency Hz

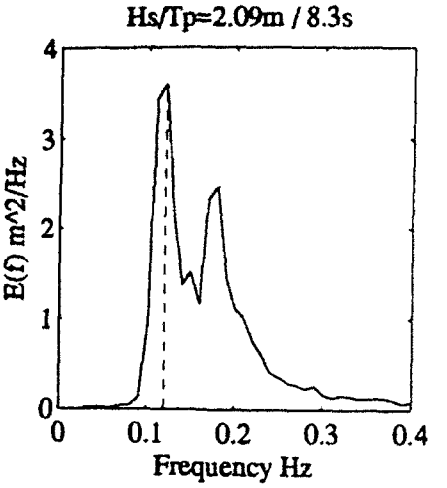

Buoy CERC 24-10-90 06:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 7.4/295; md/pd= 343/335

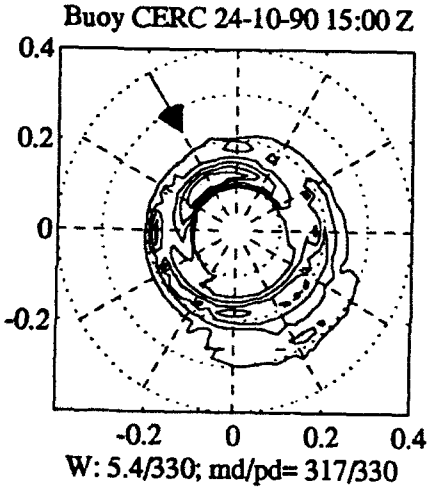

Hs/Tp=2.84m / 9s
10
8
6
4
2
0
E(f) m^2/Hz
0
0.1
0.2
0.3
0.4
Frequency Hz

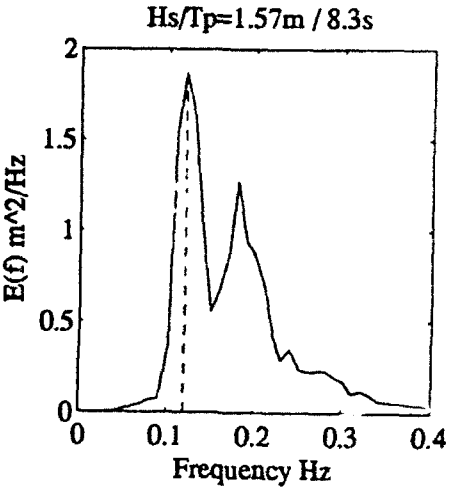

Buoy CERC 24-10-90 09:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 7.8/301; md/pd= 350/340

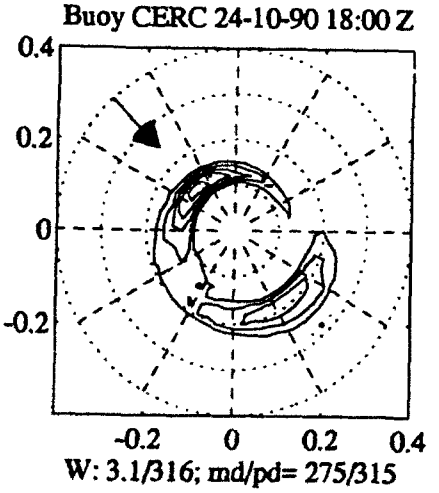

Hs/Tp=2.56m / 9s
8
6
4
2
0
E(f) m^2/Hz
0
0.1
0.2
0.3
0.4
Frequency Hz

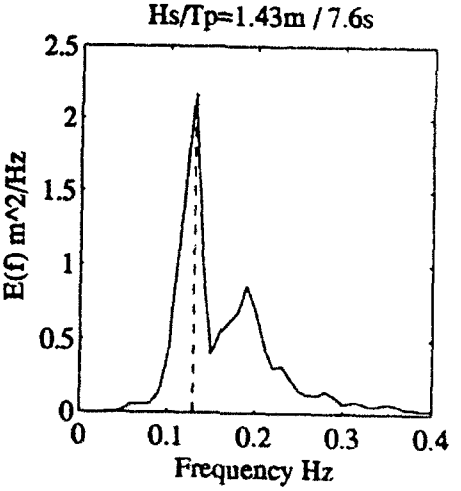

Buoy CERC 24-10-90 12:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 5.6/316; md/pd= 9/335

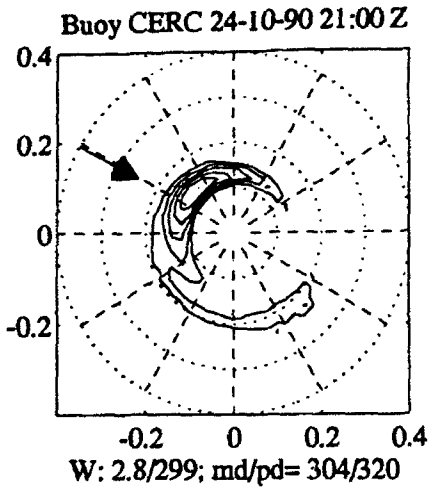

Hs/Tp=2.09m / 8.3s
E(f) m^2/Hz
4
3
2
1
0
0
0.1
0.2
0.3
0.4
Frequency Hz

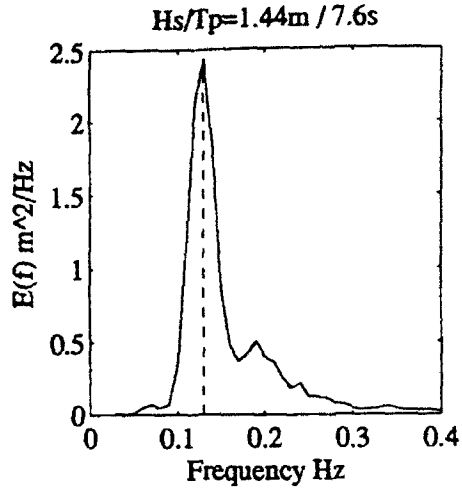

Buoy CERC 24-10-90 15:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 5.4/330; md/pd= 317/330

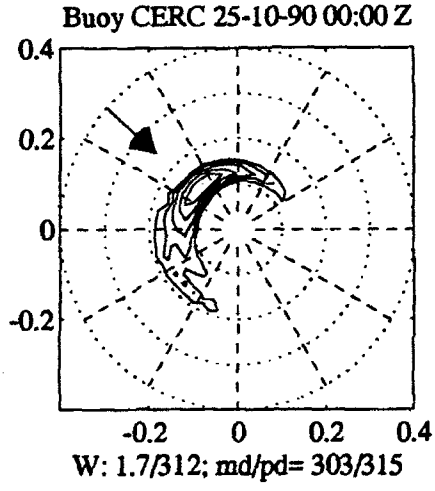

Hs/Tp=1.57m / 8.3s
E(f) m^2/Hz
2
1.5
1
0.5
0
0
0.1
0.2
0.3
0.4
Frequency Hz

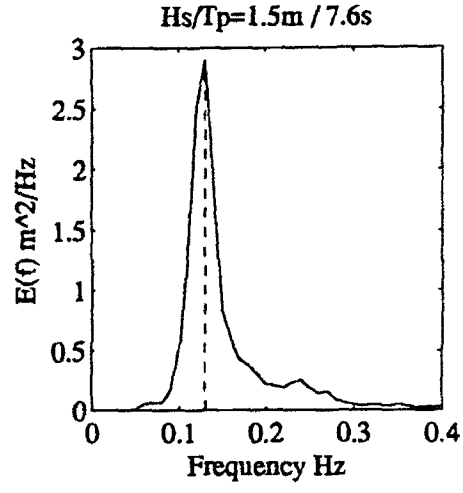

Buoy CERC 24-10-90 18:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 3.1/316; md/pd= 275/315

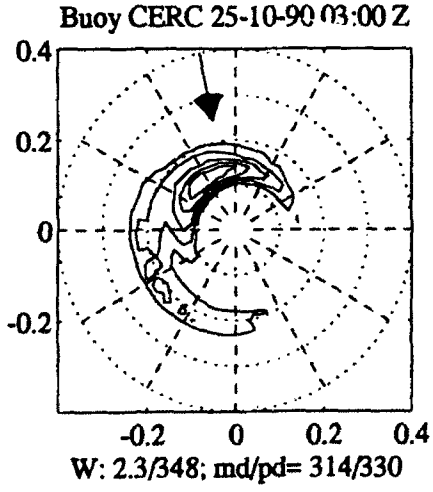

Hs/Tp=1.43m / 7.6s
E(f) m^2/Hz
2.5
2
1.5
1
0.5
0
0
0.1
0.2
0.3
0.4
Frequency Hz

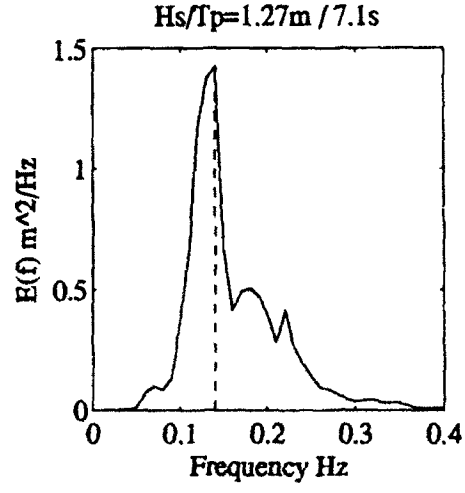

Buoy CERC 24-10-90 21:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 2.8/299; md/pd= 304/320

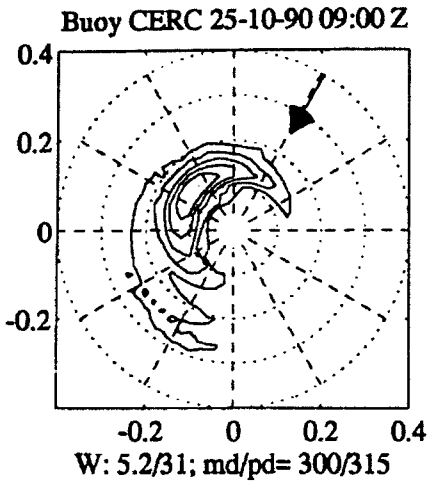

Hs/Tp=1.44m / 7.6s
E(f) m^2/Hz
2.5
2
1.5
1
0.5
0
0
0.1
0.2
0.3
0.4
Frequency Hz

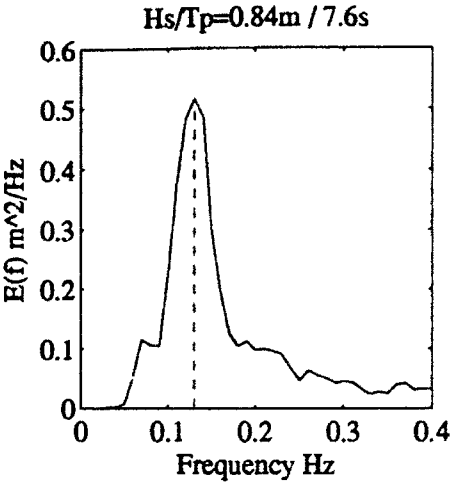

Buoy CERC 25-10-90 00:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 1.7/312; md/pd= 303/315

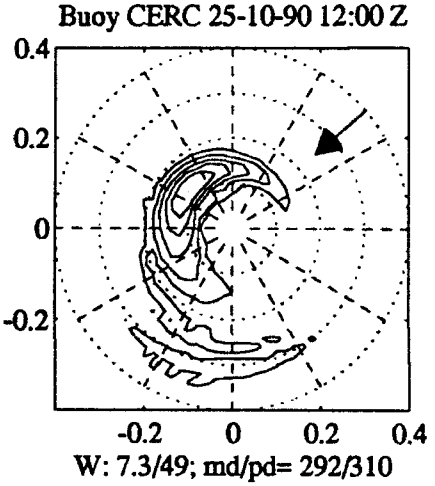

Hs/Tp=1.5m / 7.6s
E(f) m^2/Hz
3
2.5
2
1.5
1
0.5
0
0
0.1
0.2
0.3
0.4
Frequency Hz

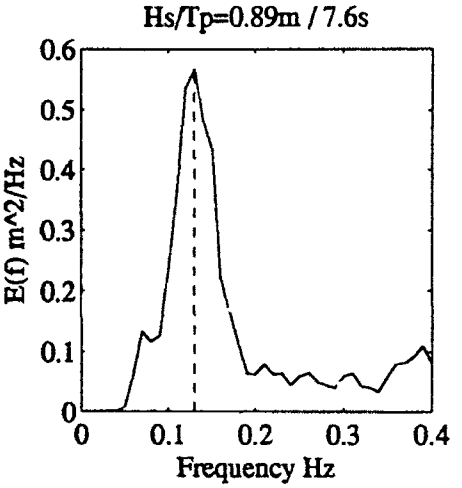

Buoy CERC 25-10-90 03:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 2.3/348; md/pd= 314/330

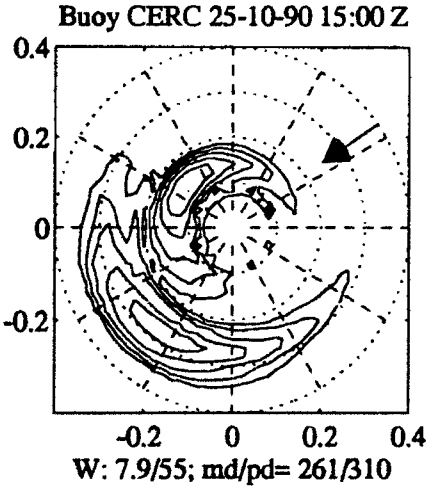

Hs/Tp=1.27m / 7.1s
E(f) m^2/Hz
1.5
1
0.5
0
0
0.1
0.2
0.3
0.4
Frequency Hz

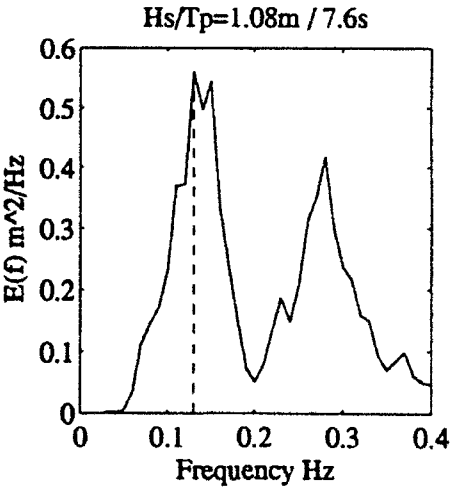

Buoy CERC 25-10-90 09:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 5.2/31; md/pd= 300/315

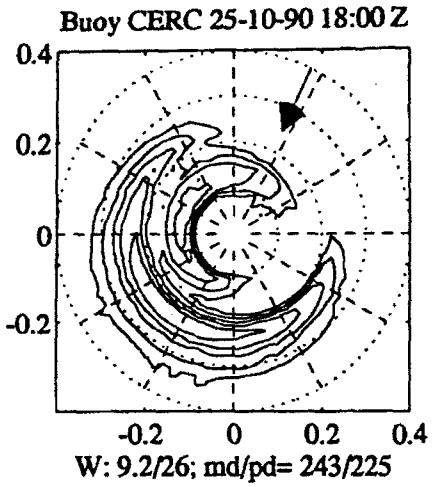

Hs/Tp=0.84m / 7.6s
E(f) m^2/Hz
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.1
0.2
0.3
0.4
Frequency Hz

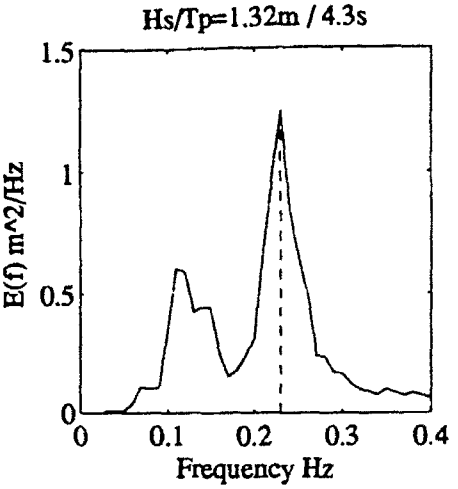

Buoy CERC 25-10-90 12:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 7.3/49; md/pd= 292/310

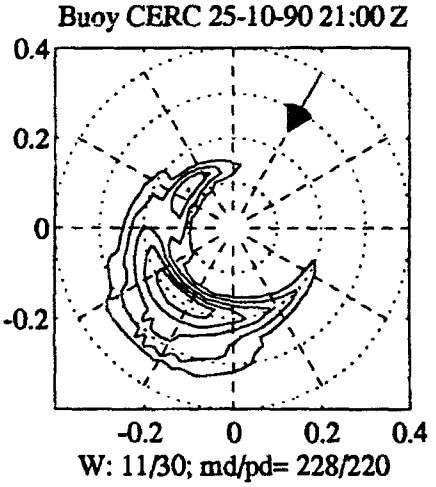

Hs/Tp=0.89m / 7.6s
E(f) m^2/Hz
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.1
0.2
0.3
0.4
Frequency Hz

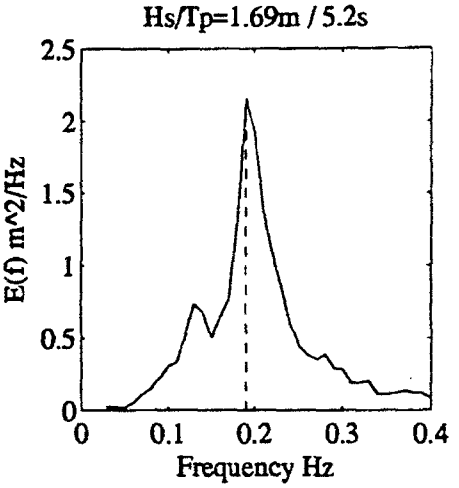

Buoy CERC 25-10-90 15:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 7.9/55; md/pd= 261/310

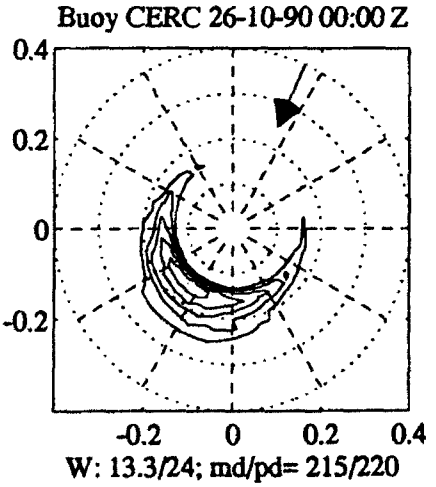

Hs/Tp=1.08m / 7.6s
E(f) m^2/Hz
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.1
0.2
0.3
0.4
Frequency Hz

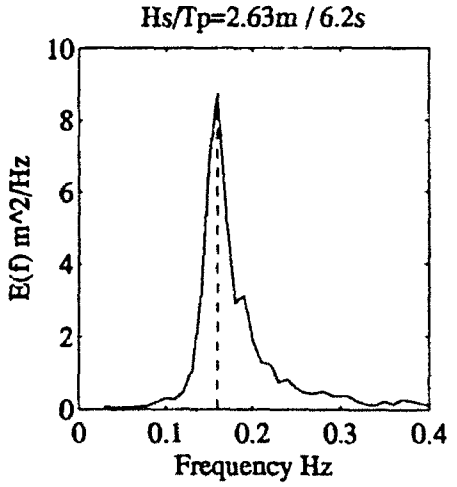

Buoy CERC 25-10-90 18:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 9.2/26; md/pd= 243/225

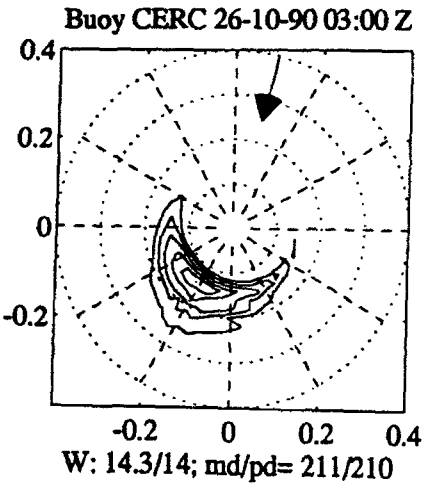

Hs/Tp=1.32m / 4.3s
E(f) m^2/Hz
1.5
1
0.5
0
0
0.1
0.2
0.3
0.4
Frequency Hz

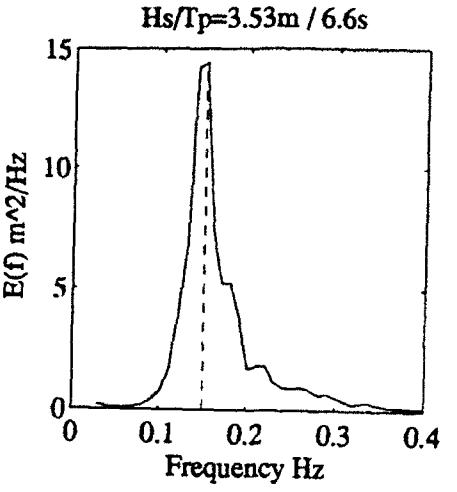

Buoy CERC 25-10-90 21:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 11/30; md/pd= 228/220

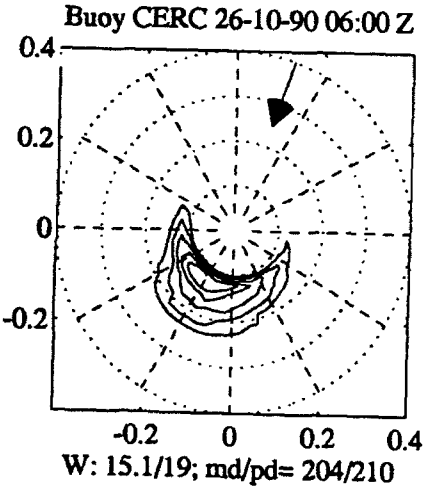

Hs/Tp=1.69m / 5.2s
E(f) m^2/Hz
2.5
2
1.5
1
0.5
0
0
0.1
0.2
0.3
0.4
Frequency Hz

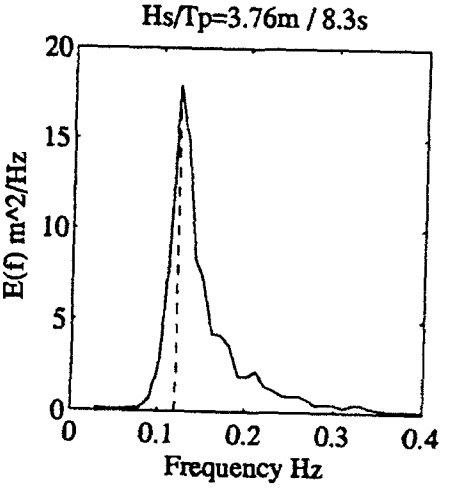

Buoy CERC 26-10-90 00:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 13.3/24; md/pd= 215/220

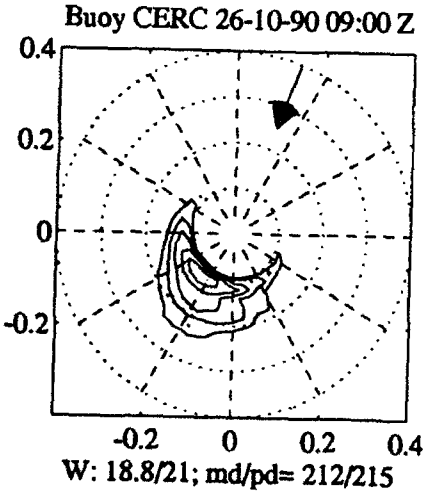

Hs/Tp=2.63m / 6.2s
E(f) m^2/Hz
10
8
6
4
2
0
0
0.1
0.2
0.3
0.4
Frequency Hz

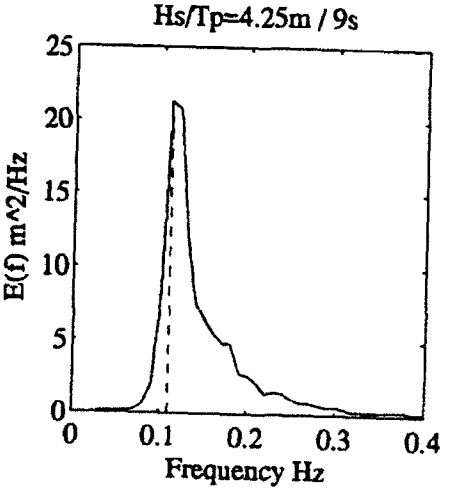

Buoy CERC 26-10-90 03:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 14.3/14; md/pd= 211/210

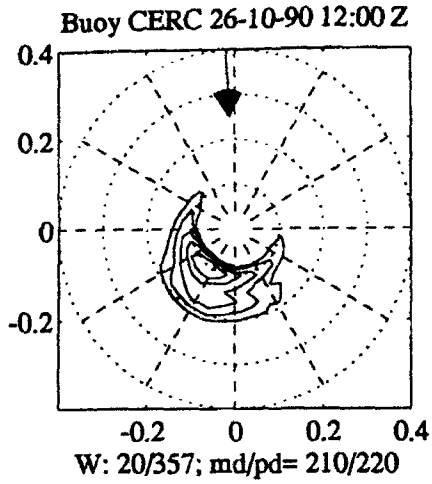

Hs/Tp=3.53m / 6.6s
E(f) m^2/Hz
15
10
5
0
0
0.1
0.2
0.3
0.4
Frequency Hz

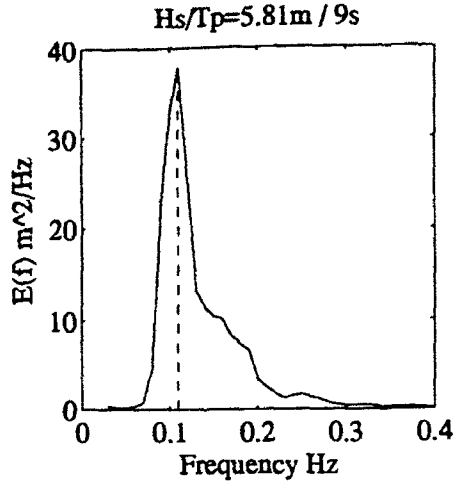

Buoy CERC 26-10-90 06:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 15.1/19; md/pd= 204/210

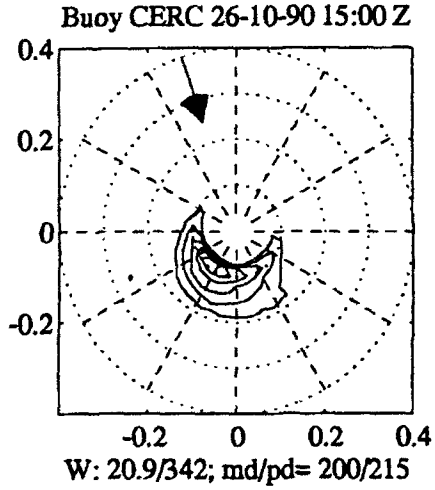

Hs/Tp=3.76m / 8.3s
E(f) m^2/Hz
20
15
10
5
0
0
0.1
0.2
0.3
0.4
Frequency Hz

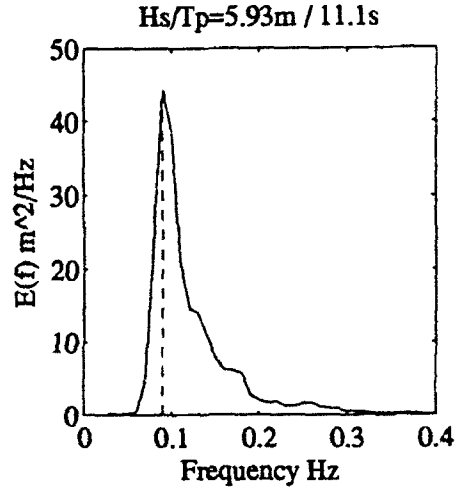

Buoy CERC 26-10-90 09:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 18.8/21; md/pd= 212/215

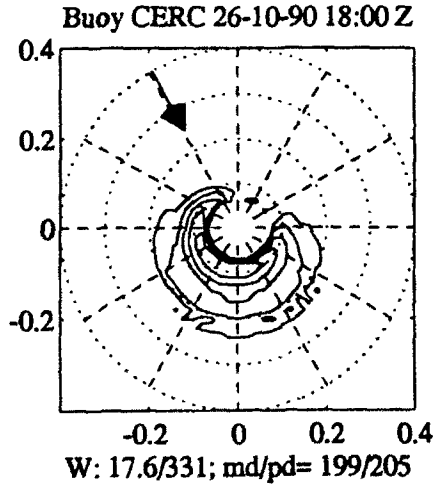

Hs/Tp=4.25m / 9s
E(f) m^2/Hz
25
20
15
10
5
0
0
0.1
0.2
0.3
0.4
Frequency Hz

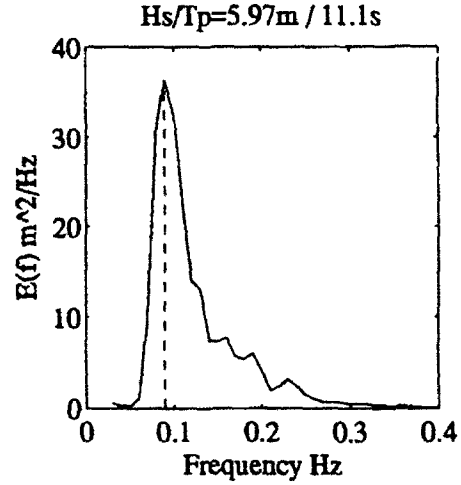

Buoy CERC 26-10-90 12:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 20/357; md/pd= 210/220

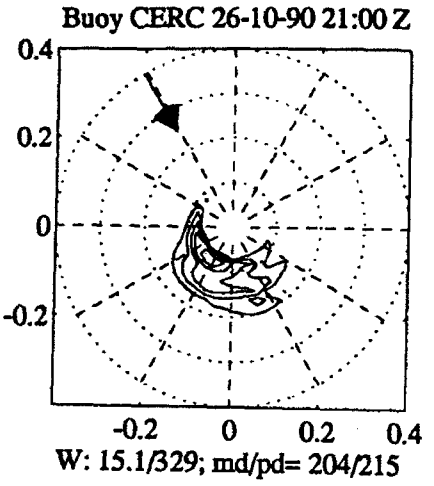

Hs/Tp=5.81m / 9s
E(f) m^2/Hz
40
30
20
10
0
0
0.1
0.2
0.3
0.4
Frequency Hz

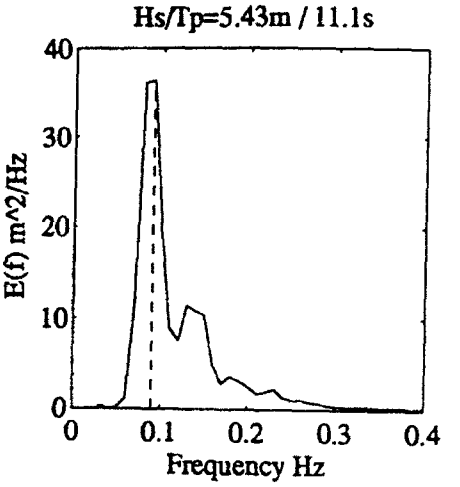

Buoy CERC 26-10-90 15:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 20.9/342; md/pd= 200/215

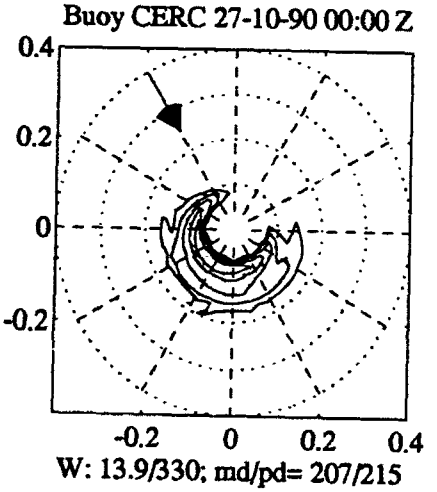

Hs/Tp=5.93m / 11.1s
E(f) m^2/Hz
50
40
30
20
10
0
0
0.1
0.2
0.3
0.4
Frequency Hz

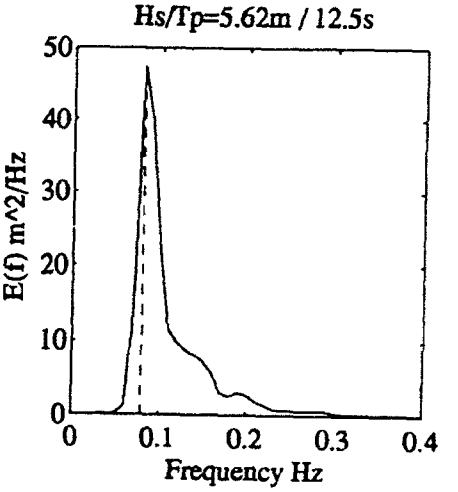

Buoy CERC 26-10-90 18:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 17.6/331; md/pd= 199/205

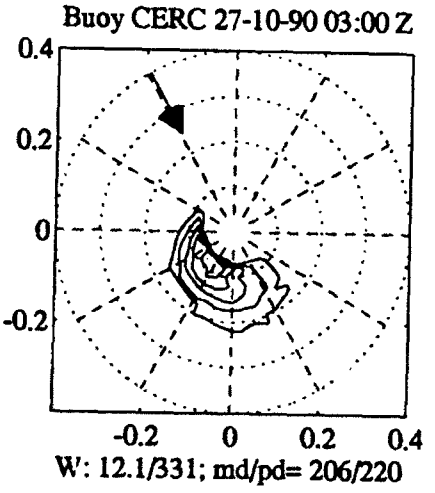

Hs/Tp=5.97m / 11.1s
E(f) m^2/Hz
40
30
20
10
0
0
0.1
0.2
0.3
0.4
Frequency Hz

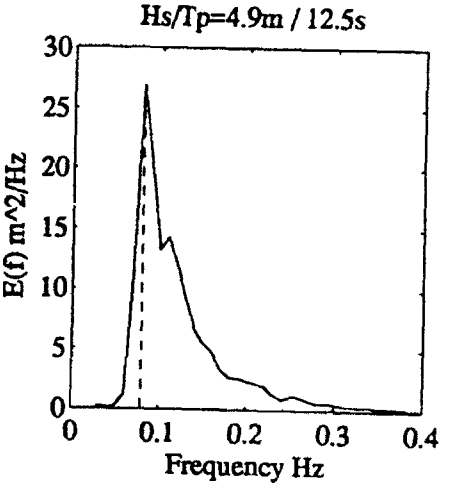

Buoy CERC 26-10-90 21:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 15.1/329; md/pd= 204/215

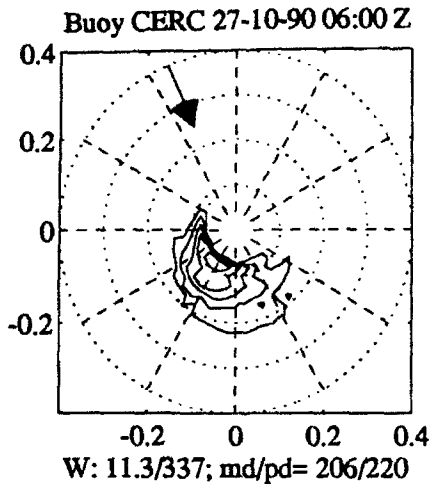

Hs/Tp=5.43m / 11.1s
E(f) m^2/Hz
40
30
20
10
0
0
0.1
0.2
0.3
0.4
Frequency Hz

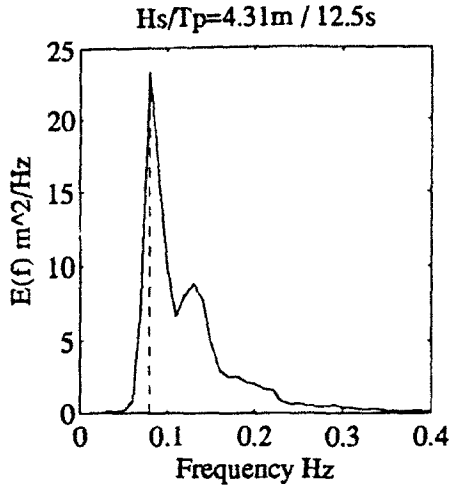

Buoy CERC 27-10-90 00:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 13.9/330; md/pd= 207/215

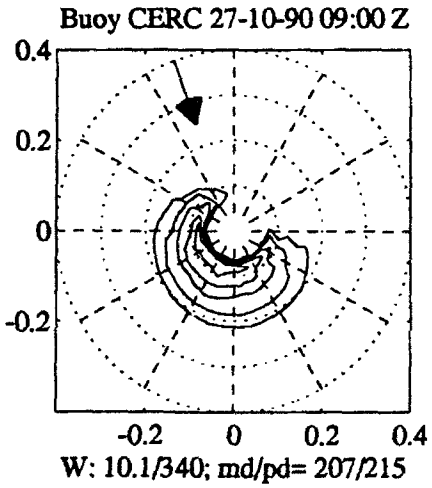

Hs/Tp=5.62m / 12.5s
E(f) m^2/Hz
50
40
30
20
10
0
0
0.1
0.2
0.3
0.4
Frequency Hz

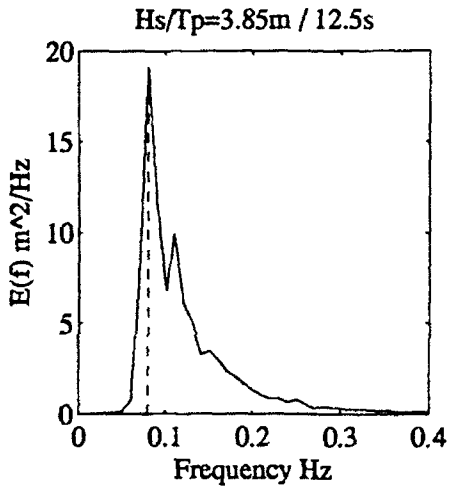

Buoy CERC 27-10-90 03:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 12.1/331; md/pd= 206/220

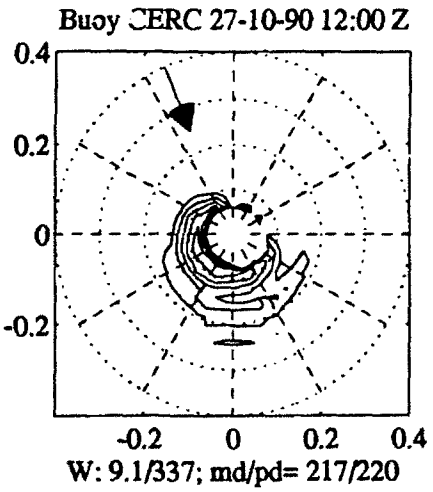

Hs/Tp=4.9m / 12.5s
E(f) m^2/Hz
30
25
20
15
10
5
0
0
0.1
0.2
0.3
0.4
Frequency Hz

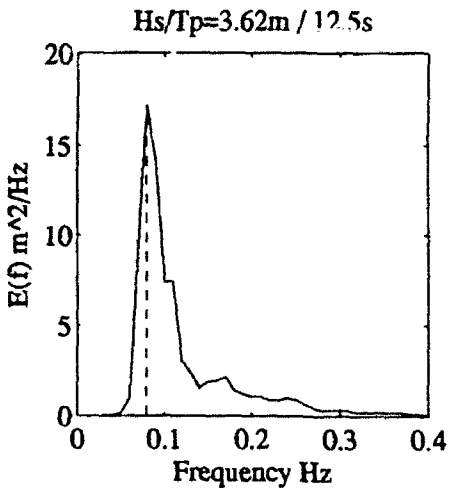

Buoy CERC 27-10-90 06:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 11.3/337; md/pd= 206/220

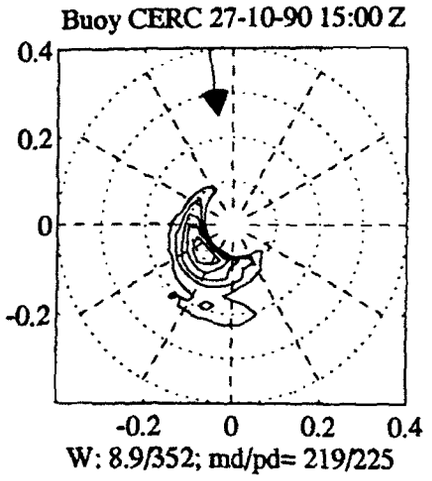

Hs/Tp=4.31m / 12.5s
25
20
15
10
5
0
E(f) m^2/Hz
0
0.1
0.2
0.3
0.4
Frequency Hz

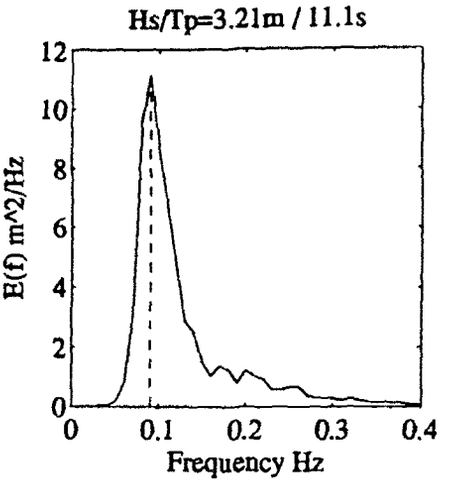

Buoy CERC 27-10-90 09:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 10.1/340; md/pd= 207/215

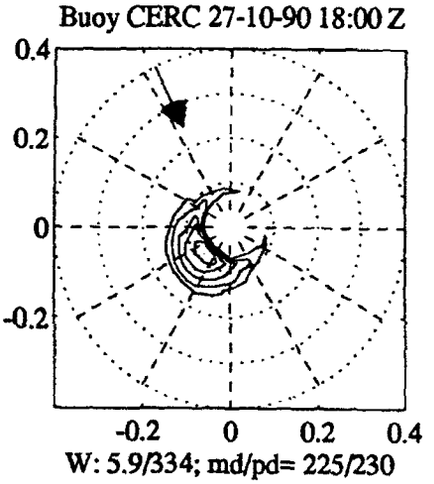

Hs/Tp=3.85m / 12.5s
20
15
10
5
0
E(f) m^2/Hz
0
0.1
0.2
0.3
0.4
Frequency Hz

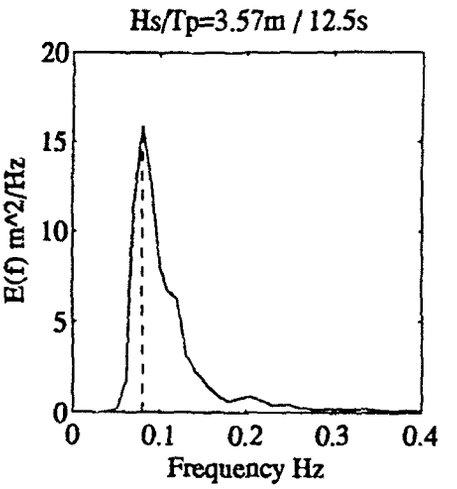

Buoy CERC 27-10-90 12:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 9.1/337; md/pd= 217/220

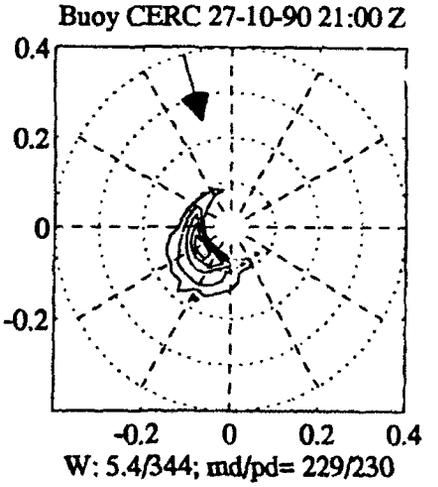

Hs/Tp=3.62m / 12.5s
20
15
10
5
0
E(f) m^2/Hz
0
0.1
0.2
0.3
0.4
Frequency Hz

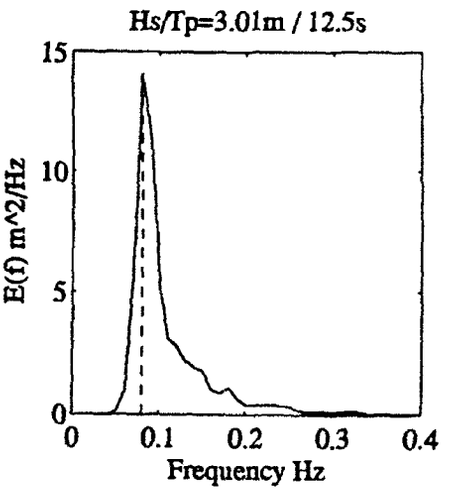

Buoy CERC 27-10-90 15:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 8.9/352; md/pd= 219/225

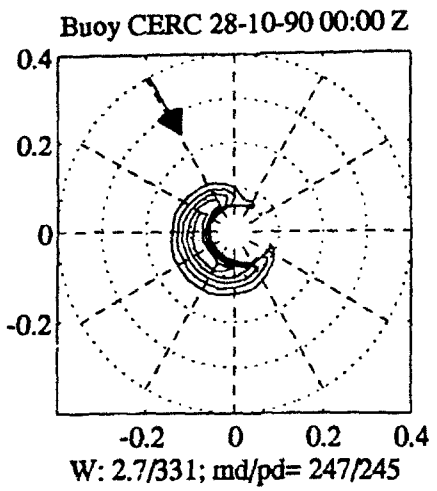

Hs/Tp=3.21m / 11.1s
E(f) m^2/Hz
12
10
8
6
4
2
0
0
0.1
0.2
0.3
0.4
Frequency Hz

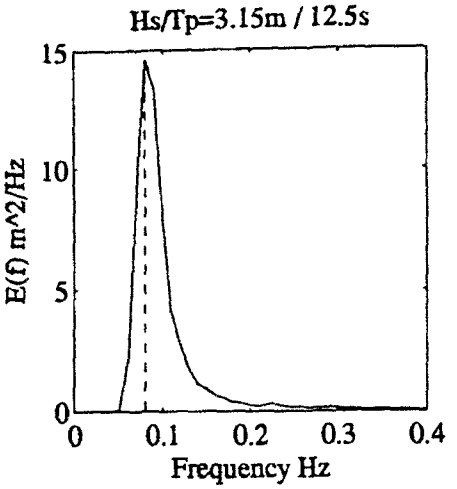

Buoy CERC 27-10-90 18:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 5.9/334; md/pd= 225/230

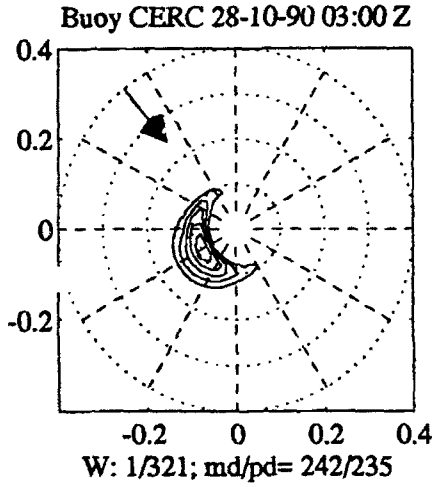

Hs/Tp=3.57m / 12.5s
E(f) m^2/Hz
20
15
10
5
0
0
0.1
0.2
0.3
0.4
Frequency Hz

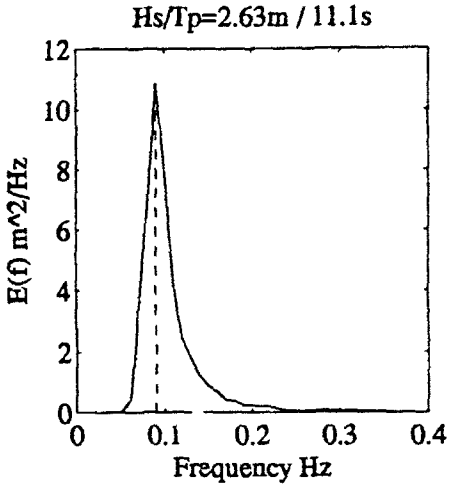

Buoy CERC 27-10-90 21:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 5.4/344; md/pd= 229/230

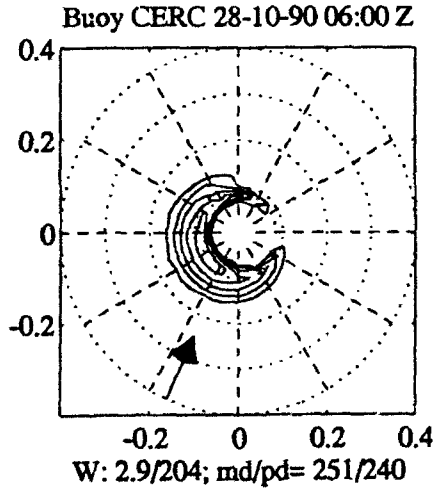

Hs/Tp=3.01m / 12.5s
E(f) m^2/Hz
15
10
5
0
0
0.1
0.2
0.3
0.4
Frequency Hz

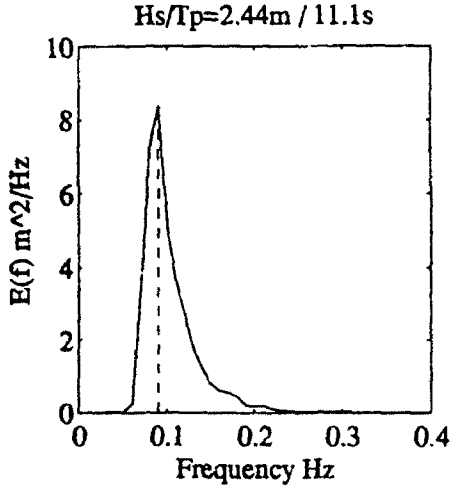

Buoy CERC 28-10-90 00:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 2.7/331; md/pd= 247/245

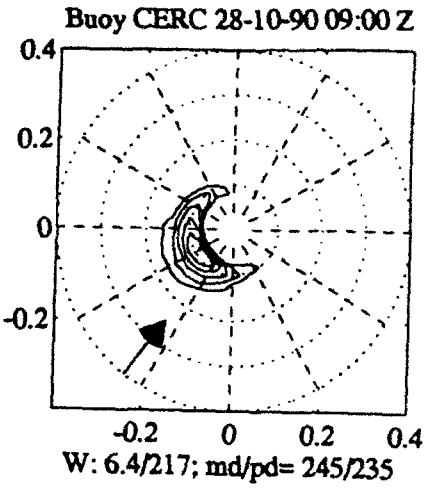

Hs/Tp=3.15m / 12.5s
15
10
5
0
E(f) m^2/Hz
0
0.1
0.2
0.3
0.4
Frequency Hz

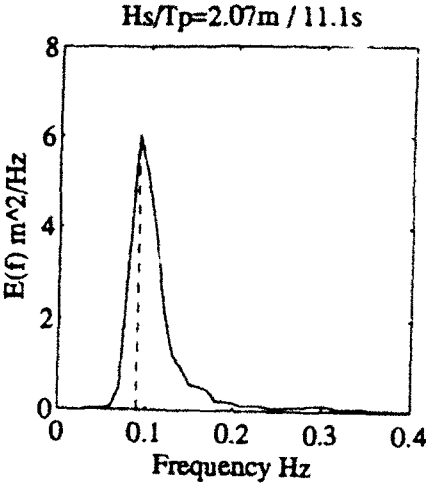

Buoy CERC 28-10-90 03:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 1/321; md/pd= 242/235

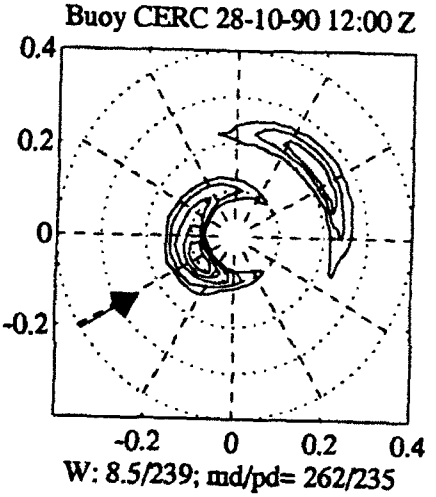

Hs/Tp=2.63m / 11.1s
12
10
8
6
4
2
0
E(f) m^2/Hz
0
0.1
0.2
0.3
0.4
Frequency Hz

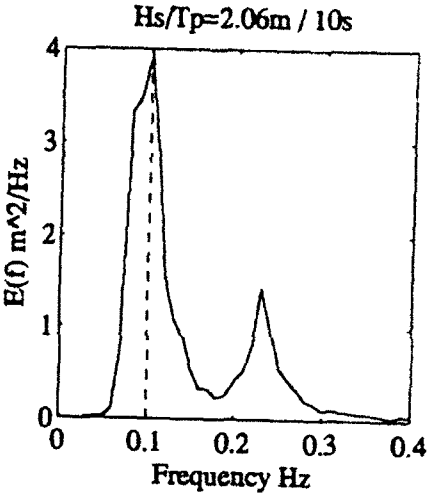

Buoy CERC 28-10-90 06:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 2.9/204; md/pd= 251/240

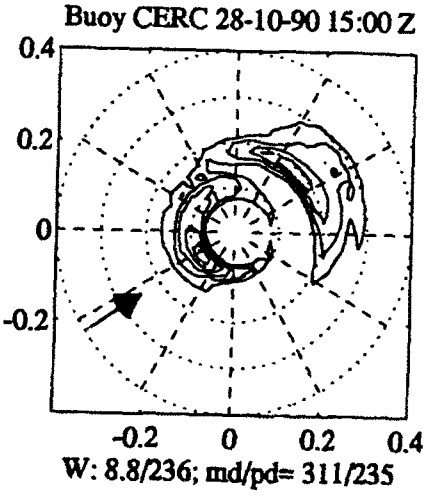

Hs/Tp=2.44m / 11.1s
10
8
6
4
2
0
E(f) m^2/Hz
0
0.1
0.2
0.3
0.4
Frequency Hz

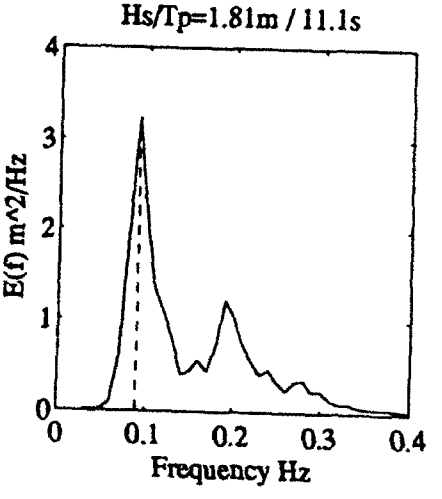

Buoy CERC 28-10-90 09:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 6.4/217; md/pd= 245/235

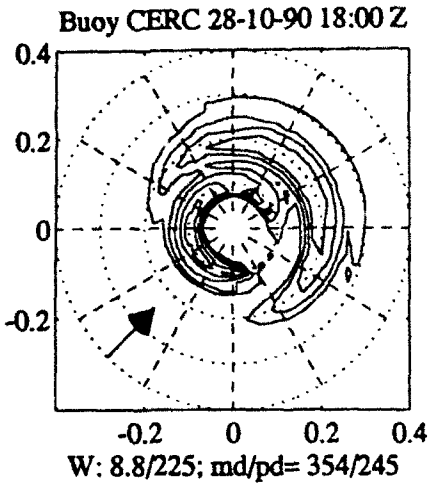

Hs/Tp=2.07m / 11.1s
E(f) m^2/Hz
8
6
4
2
0
0
0.1
0.2
0.3
0.4
Frequency Hz

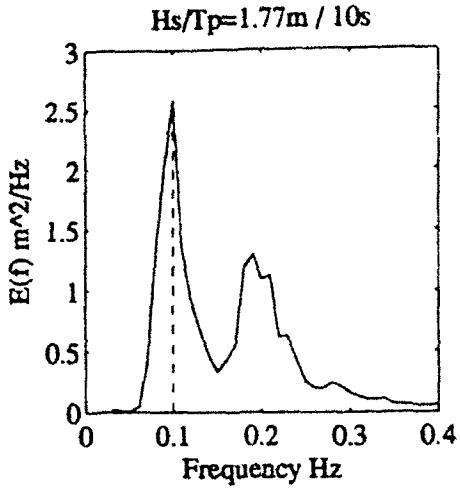

Buoy CERC 28-10-90 12:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 8.5/239; md/pd= 262/235

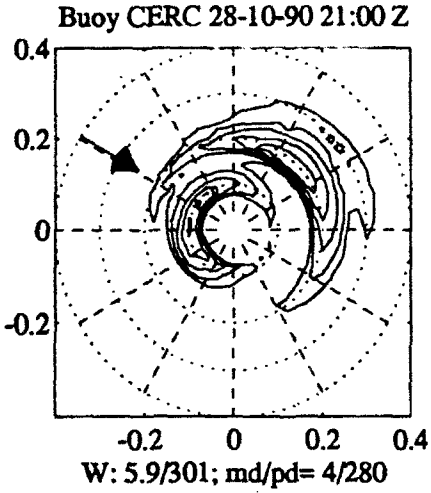

Hs/Tp=2.06m / 10s
E(f) m^2/Hz
4
3
2
1
0
0
0.1
0.2
0.3
0.4
Frequency Hz

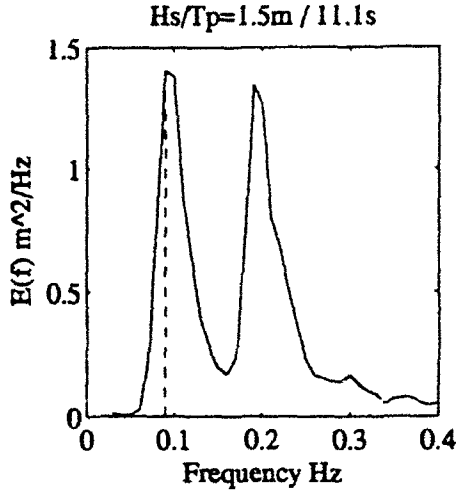

Buoy CERC 28-10-90 15:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 8.8/236; md/pd= 311/235

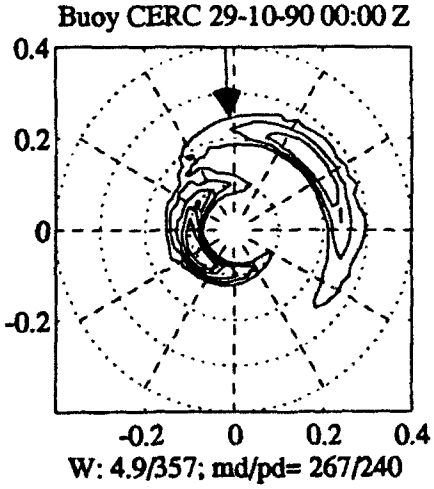

Hs/Tp=1.81m / 11.1s
E(f) m^2/Hz
4
3
2
1
0
0
0.1
0.2
0.3
0.4
Frequency Hz

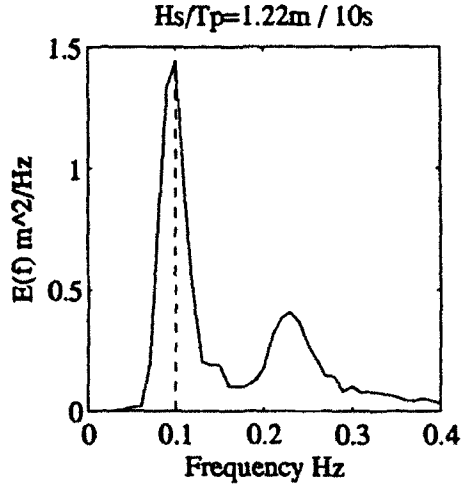

Buoy CERC 28-10-90 18:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 8.8/225; md/pd= 354/245


Hs/Tp=1.77m / 10s
E(f) m^2/Hz
3
2.5
2
1.5
1
0.5
0
0
0.1
0.2
0.3
0.4
Frequency Hz


Buoy CERC 28-10-90 21:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 5.9/301; md/pd= 4/280


Hs/Tp=1.5m / 11.1s
E(f) m^2/Hz
1.5
1
0.5
0
0
0.1
0.2
0.3
0.4
Frequency Hz

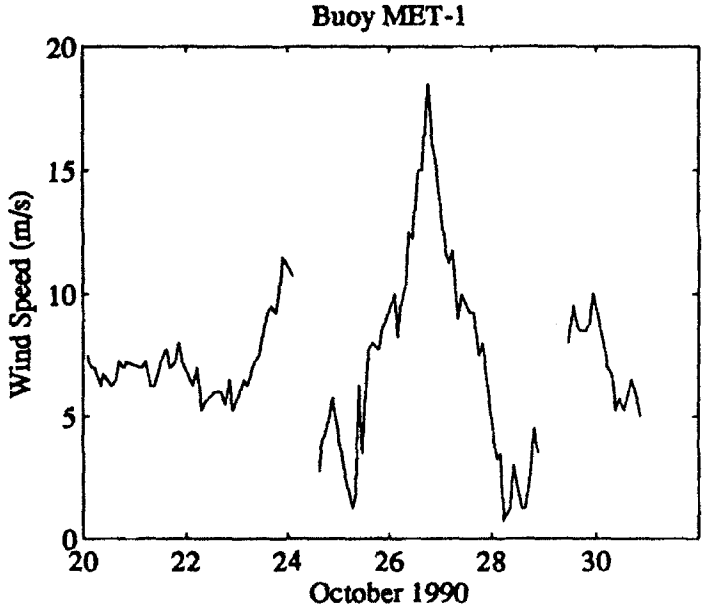

Buoy CERC 29-10-90 00:00 Z
0.4
0.2
0
-0.2
-0.2
0
0.2
0.4
W: 4.9/357; md/pd= 267/240

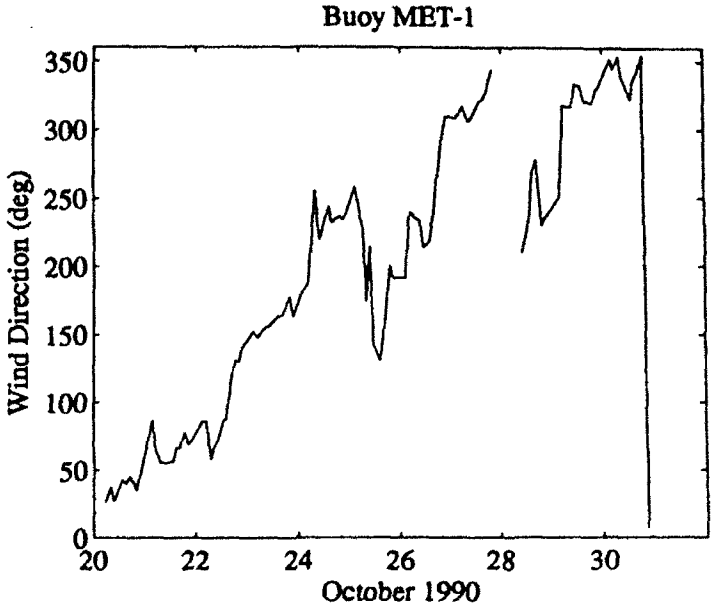

Hs/Tp=1.22m / 10s
E(f) m^2/Hz
1.5
1
0.5
0
0
0.1
0.2
0.3
0.4
Frequency Hz

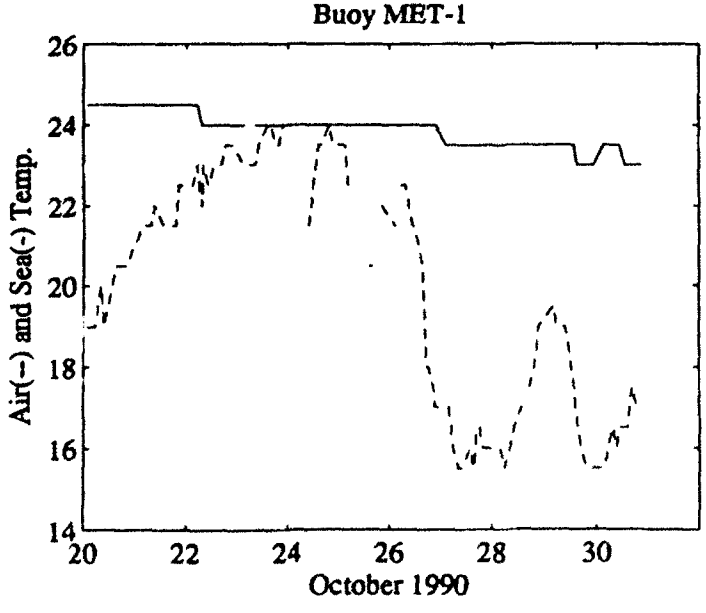
Appendix C: Time Series from MiniMet Buoys

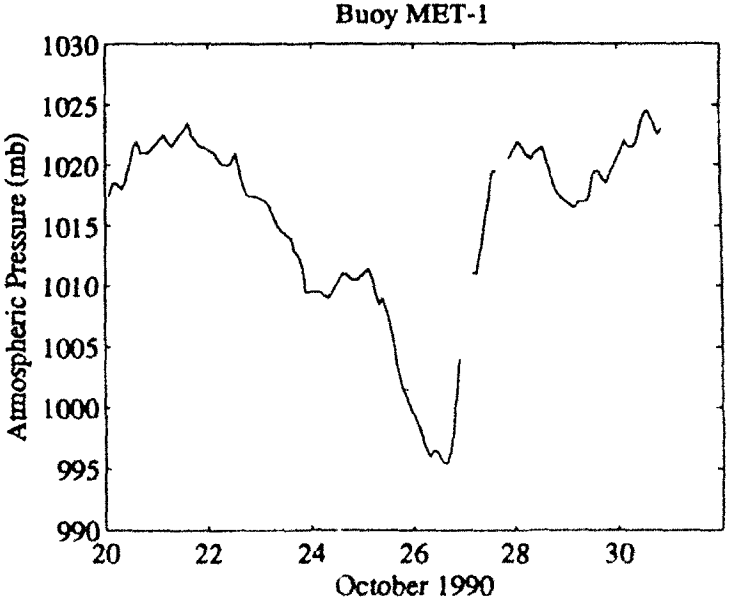
Time series plots of the observed data are presented in this appendix in the following sequence:

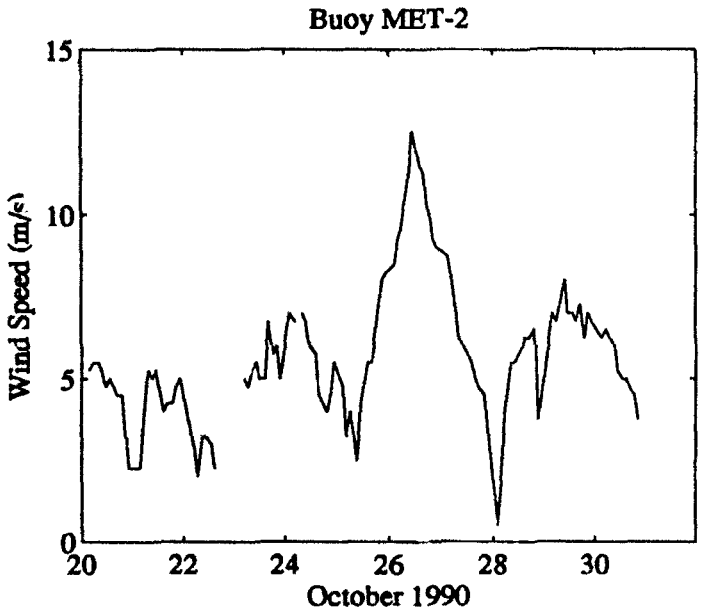
- MiniMet Buoy "MET-1" (41012, 41014)
- MiniMet Buoy "MET-2" (44018, 44022)
- MiniMet Buoy "MET-3" (44016, 44020)
- MiniMet Buoy "MET-4" (44017, 44021)

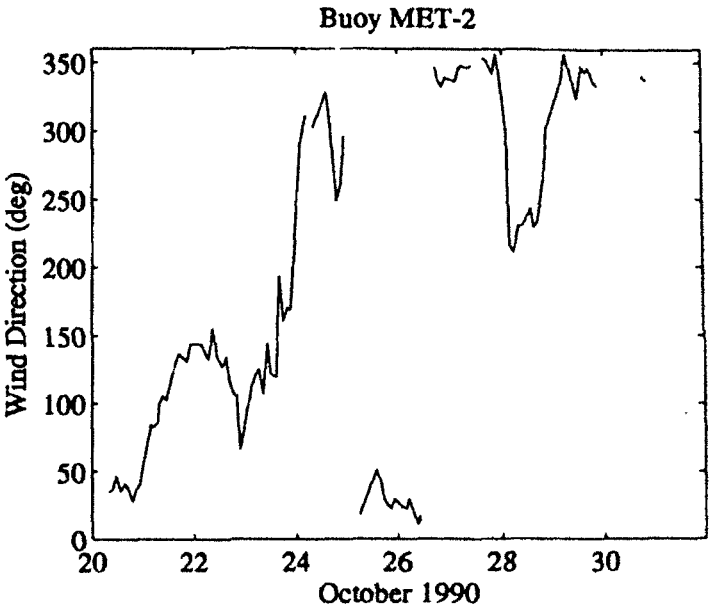

Buoy MET-1
Wind Speed (m/s)
0
5
10
15
20
20
22
24
26
28
30
October 1990

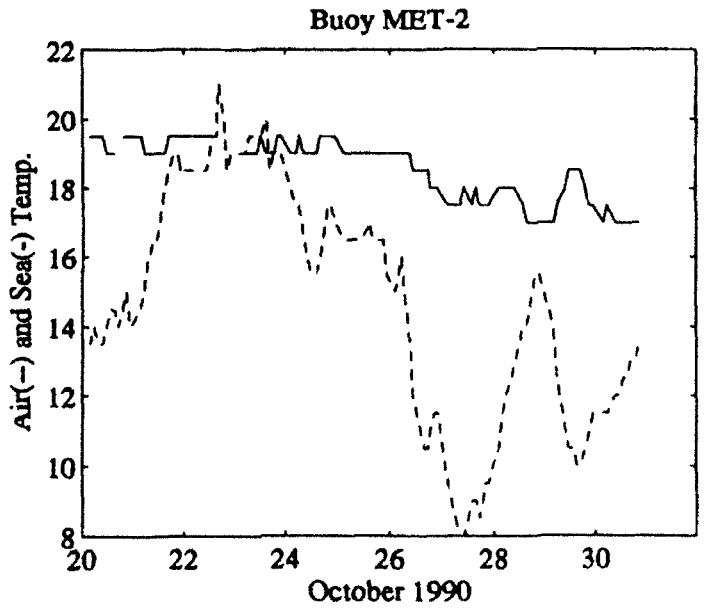

Buoy MET-1
Wind Direction (deg)
0
50
100
150
200
250
300
350
20
22
24
26
28
30
October 1990

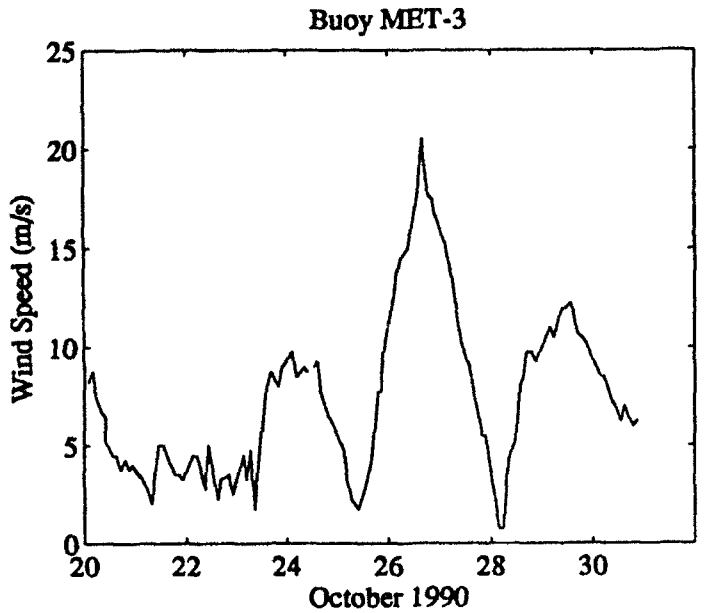

Buoy MET-1
Air(--) and Sea(-) Temp.
14
16
18
20
22
24
26
20
22
24
26
28
30
October 1990

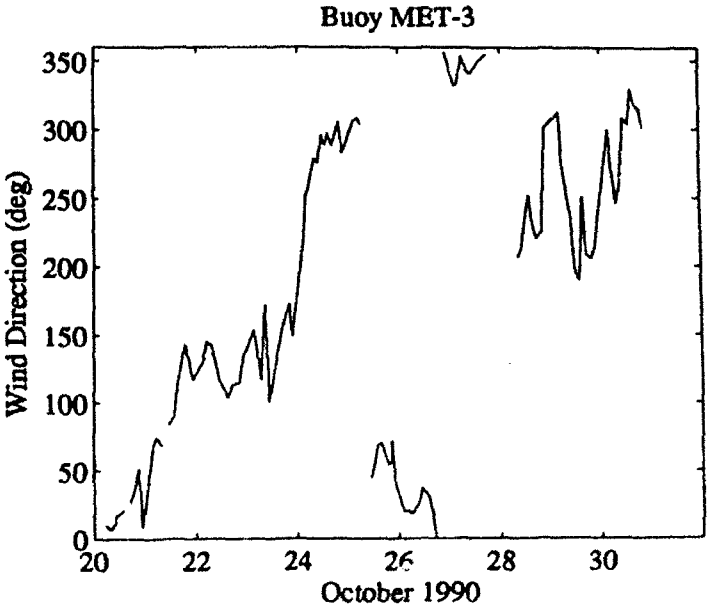

Buoy MET-1
Atmospheric Pressure (mb)
990
995
1000
1005
1010
1015
1020
1025
1030
20
22
24
26
28
30
October 1990

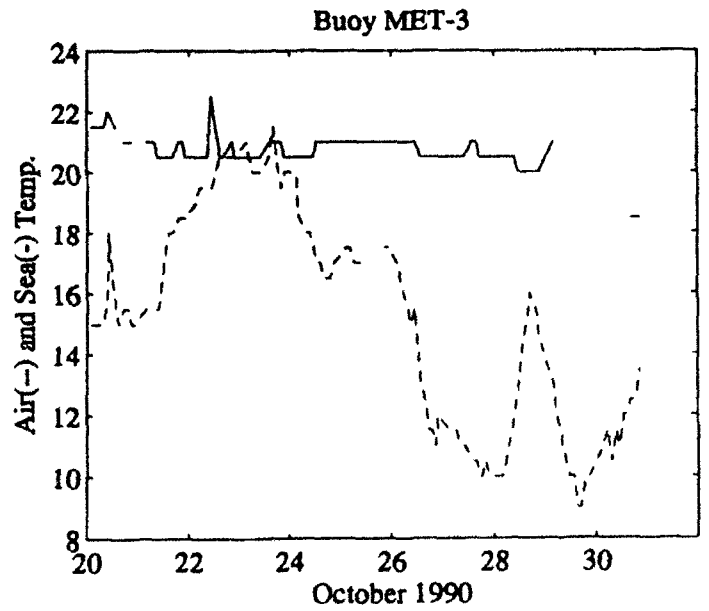

Buoy MET-2
Wind Speed (m/s)
15
10
5
0
20
22
24
26
28
30
October 1990

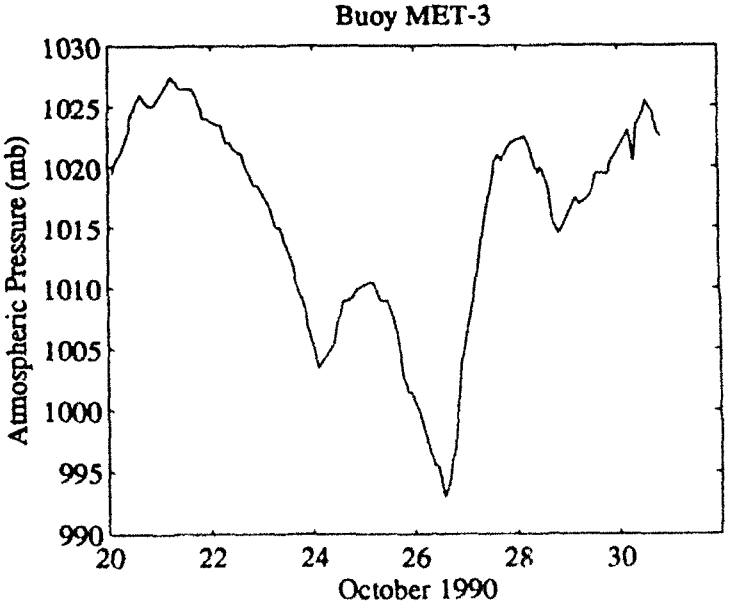

Buoy MET-2
Wind Direction (deg)
350
300
250
200
150
100
50
0
20
22
24
26
28
30
October 1990

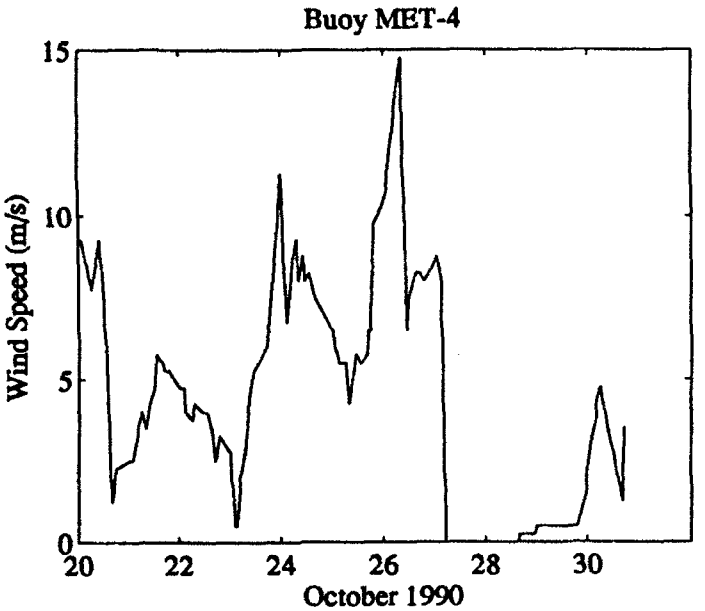

Buoy MET-2
Air(–) and Sea(-) Temp.
22
20
18
16
14
12
10
8
20
22
24
26
28
30
October 1990

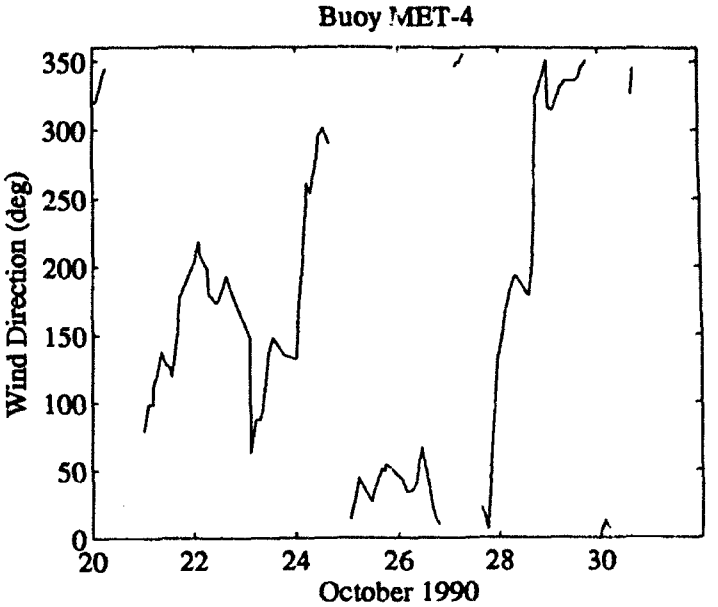

Buoy MET-3
Wind Speed (m/s)
October 1990

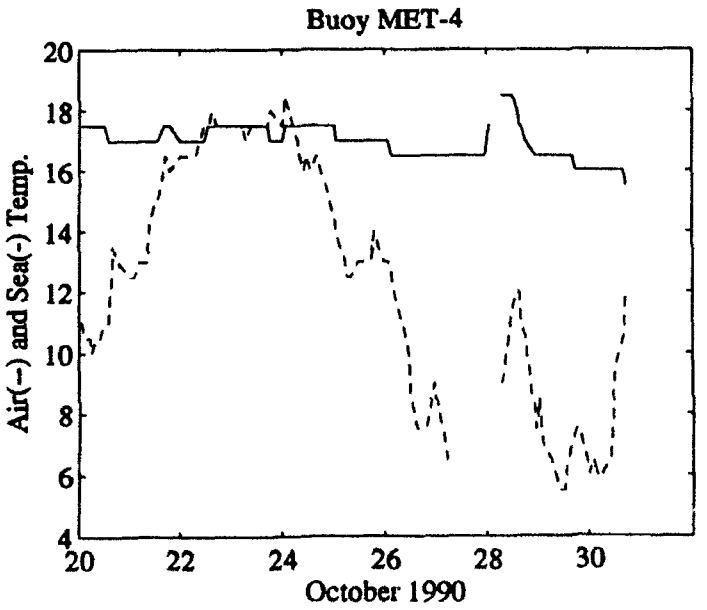

Buoy MET-3
Wind Direction (deg)
October 1990


Buoy MET-3
Air(–) and Sea(-) Temp.
October 1990


Buoy MET-3
Atmospheric Pressure (mb)
October 1990


Buoy MET-4
Wind Speed (m/s)
15
10
5
0
20
22
24
26
28
30
October 1990


Buoy MET-4
Wind Direction (deg)
350
300
250
200
150
100
50
0
20
22
24
26
28
30
October 1990


Buoy MET-4
Air(--) and Sea(-) Temp.
20
18
16
14
12
10
8
6
4
20
22
24
26
28
30
October 1990

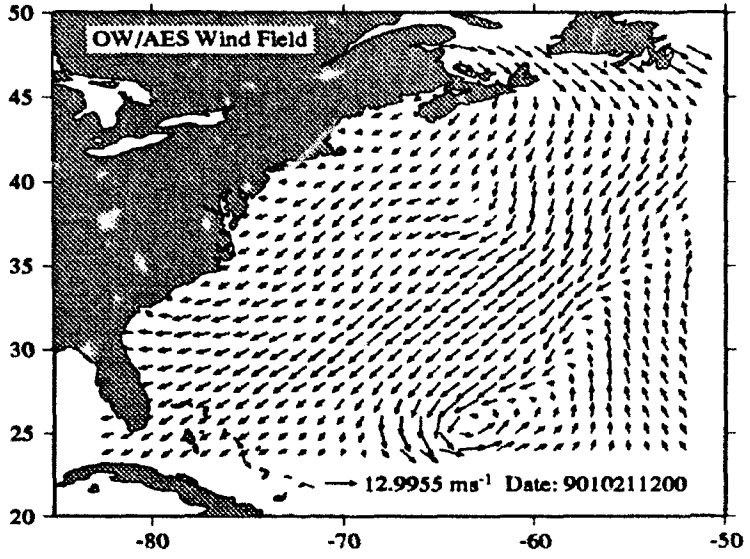
Appendix D: Custer Diagrams of Wind Fields and Wave Hindcasts

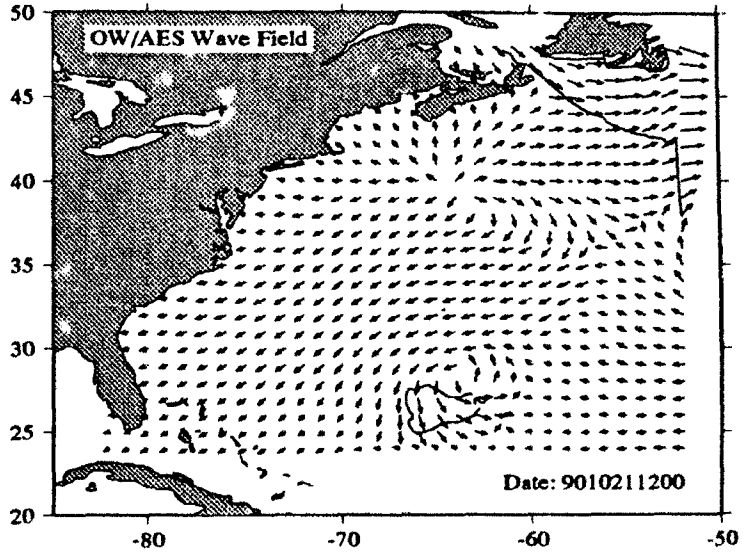
Maps of the wind vector fields (Custer diagrams) and corresponding wave height hindcasts with the ocean wave model "WAM" are presented in this appendix for six different wind field specifications. Each wind field Custer diagram presents the maximum wind speed for this time. The vectors of the wave height Custer diagram correspond to mean wave direction as computed by the WAM model. Contours of the wave heights are given in meters.

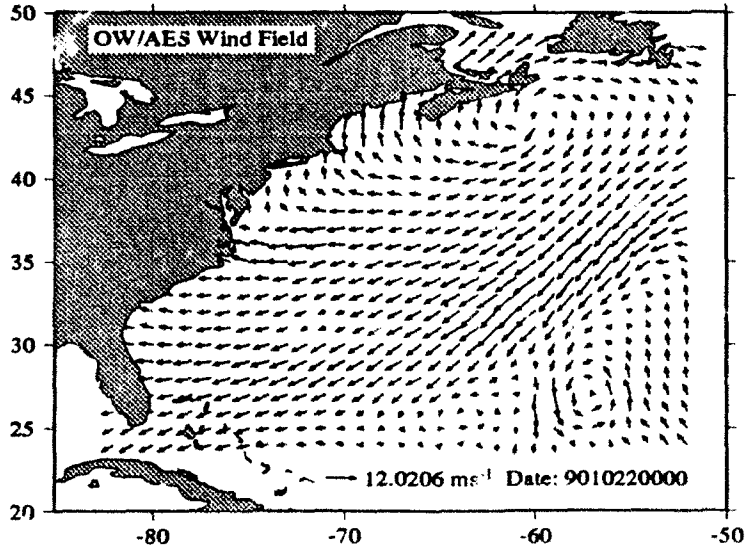
D.1: Oceanweather/Atmospheric Environment Service (OW/AES)

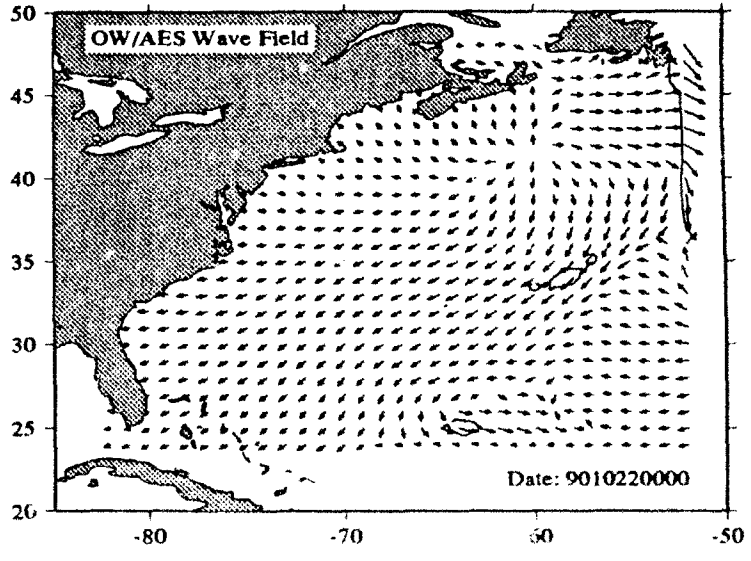
Custer diagrams are presented for the time period from 20 October 1990, 12:00 GMT to 31 October 1990, 12:00 GMT of the wind fields and corresponding wave hindcasts. Note that the frequency of maps is every 3 hr from 26-28 October, which covers the major storm period.

OW/AES Wave Field
Date: 90102012OO
OW/AES Wave Field
Date: 90102100OO
OW/AES Wind Field
17.6969 ms-1 Date: 90102012OO
OW/AES Wind Field
18.6396 ms-1 Date: 90102100OO
50
45
40
35
30
25
20
-50
-60
-70
-80


OW/AES Wind Field
12.9955 ms-1 Date: 9010211200
50
45
40
35
30
25
20
-80
-70
-60
-50


OW/AES Wave Field
Date: 9010211200
50
45
40
35
30
25
20
-80
-70
-60
-50


OW/AES Wind Field
12.0206 ms-1 Date: 9010220000
50
45
40
35
30
25
20
-80
-70
-60
-50

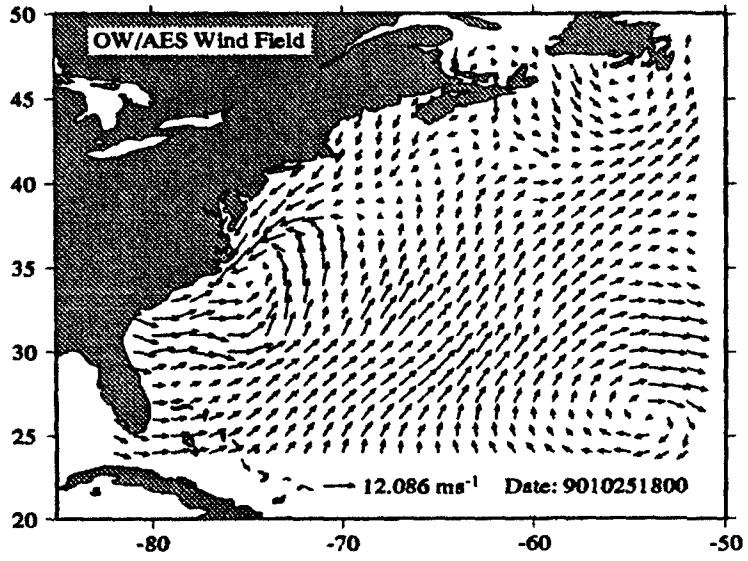

OW/AES Wave Field
Date: 9010220000
50
45
40
35
30
25
20
-80
-70
-50

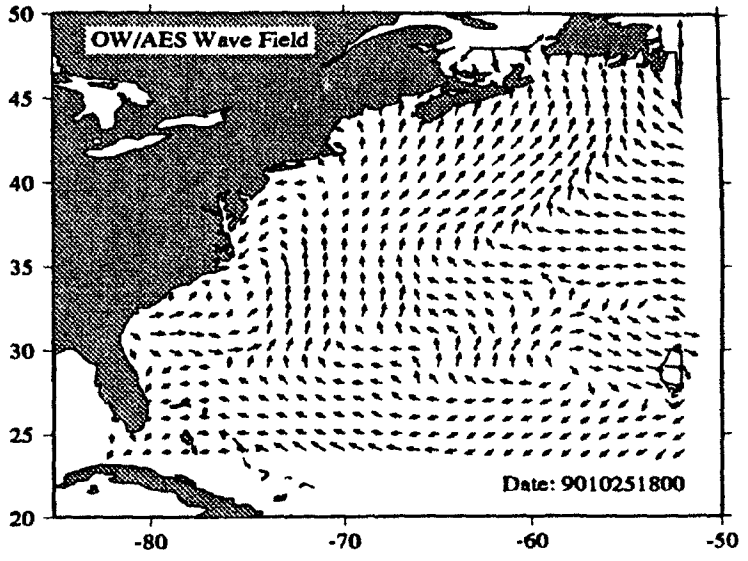
OW/AES Wind Field
14.7033 ms-1 Date: 9010221200
OW/AES Wave Field
Date: 9010221200
OW/AES Wind Field
15.3619 ms-1 Date: 9010230000
OW/AES Wave Field
Date: 9010230000
50
45
40
35
30
25
20
-50
-60
-70
-80

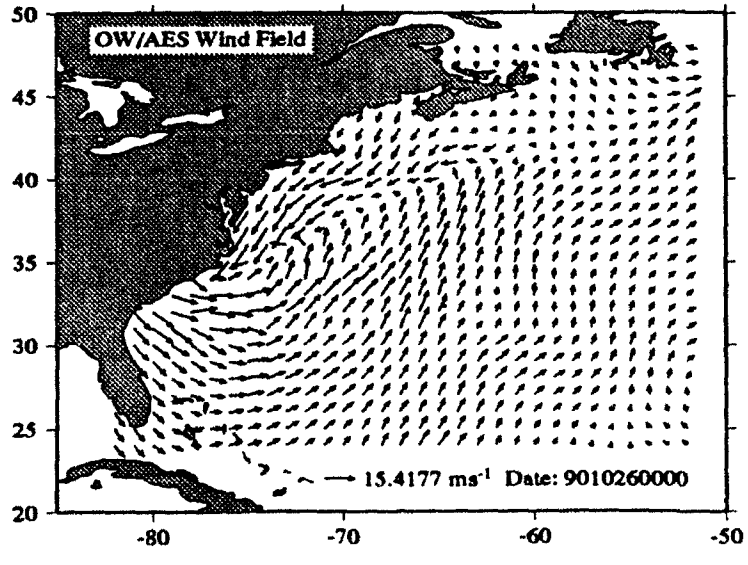
OW/AES Wind Field
17.7661 ms-1 Date: 9010231200
OW/AES Wave Field
Date: 9010231200
OW/AES Wind Field
15.8831 ms-1 Date: 9010240000
OW/AES Wave Field
Date: 9010240000
50
45
40
35
30
25
20
-50
-60
-70
-80

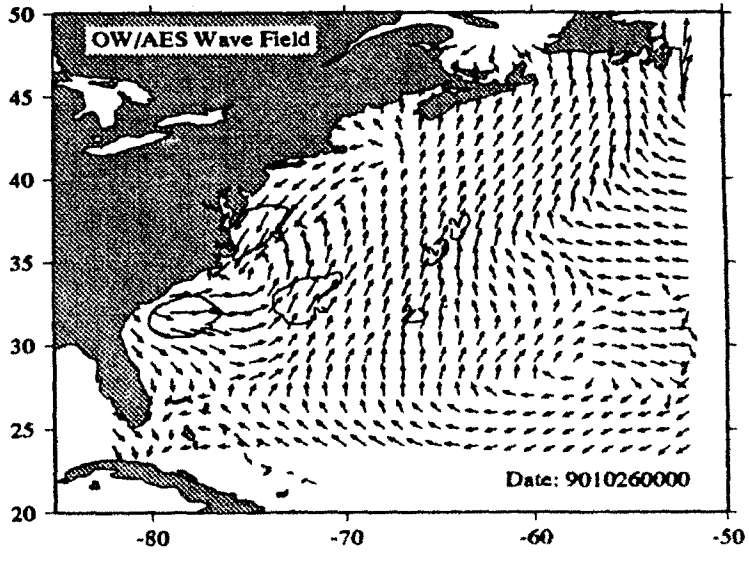
OW/AES Wave Field
Date: 9010241200
OW/AES Wave Field
Date: 9010250000
OW/AES Wind Field
14.5721 ms-1 Date: 9010241200
OW/AES Wind Field
14.6901 ms-1 Date: 9010250000

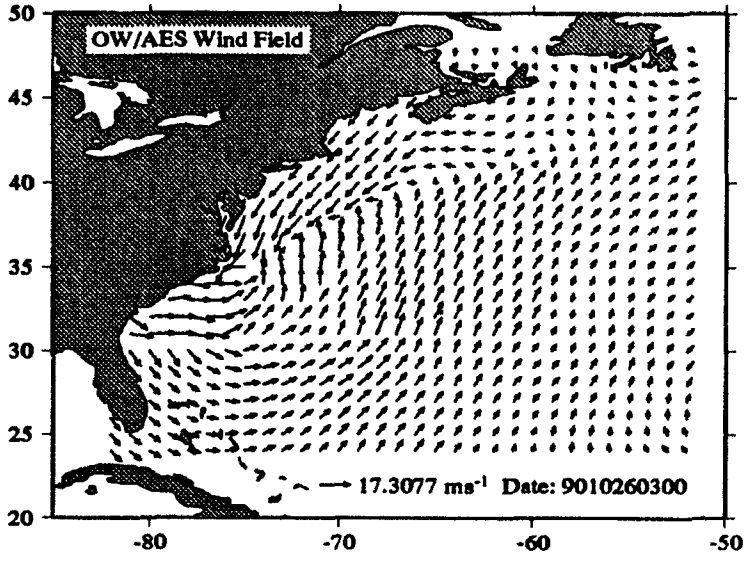
OW/AES Wind Field
16.1259 ms-1 Date: 9010250600
OW/AES Wave Field
Date: 9010250600
OW/AES Wind Field
13.6051 ms-1 Date: 9010251200
OW/AES Wave Field
Date: 9010251200
50
45
40
35
30
25
20
-50
-60
-70
-80

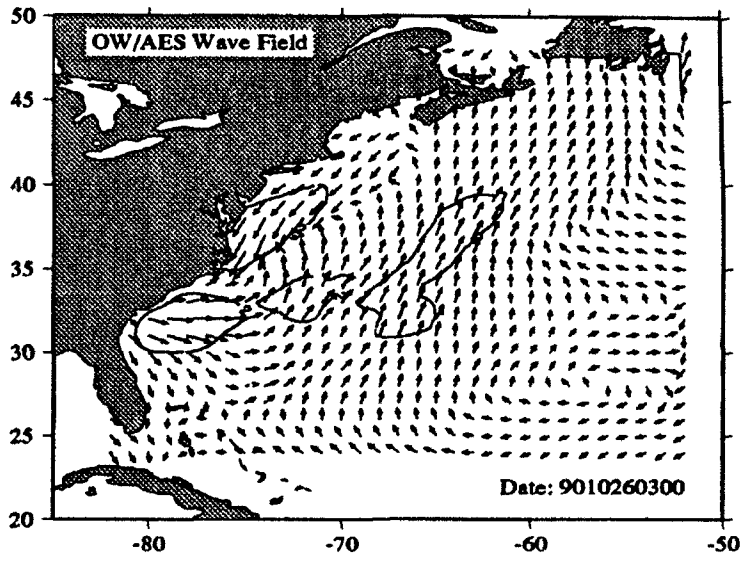

OW/AES Wind Field
12.086 ms-1 Date: 9010251800
50
45
40
35
30
25
20
-80
-70
-60
-50

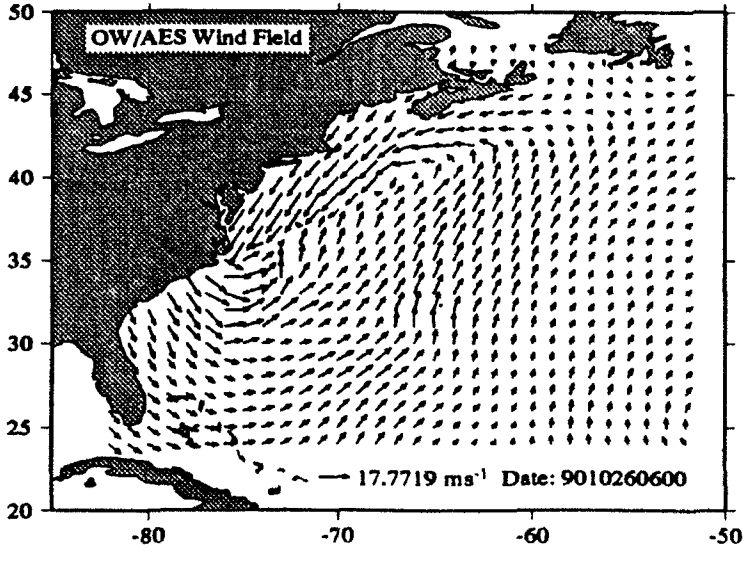

OW/AES Wave Field
Date: 9010251800
50
45
40
35
30
25
20
-80
-70
-60
-50

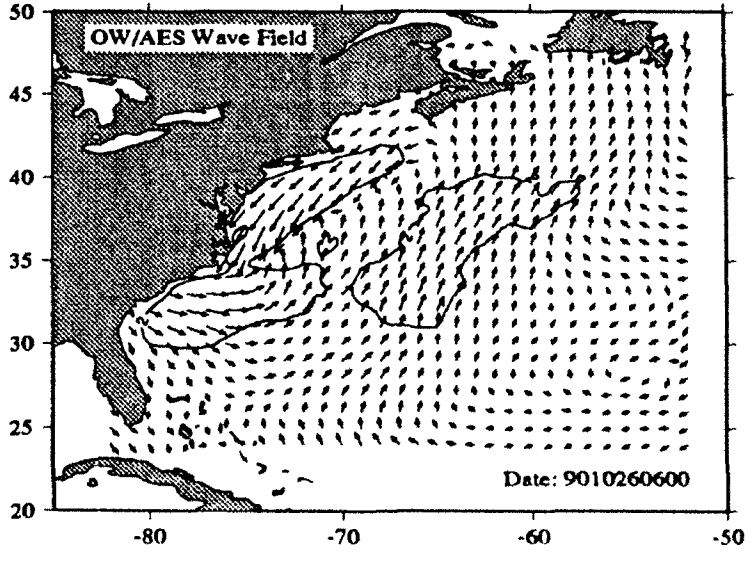

OW/AES Wind Field
15.4177 ms-1 Date: 9010260000
50
45
40
35
30
25
20
-80
-70
-60
-50


OW/AES Wave Field
Date: 9010260000
50
45
40
35
30
25
20
-80
-70
-60
-50

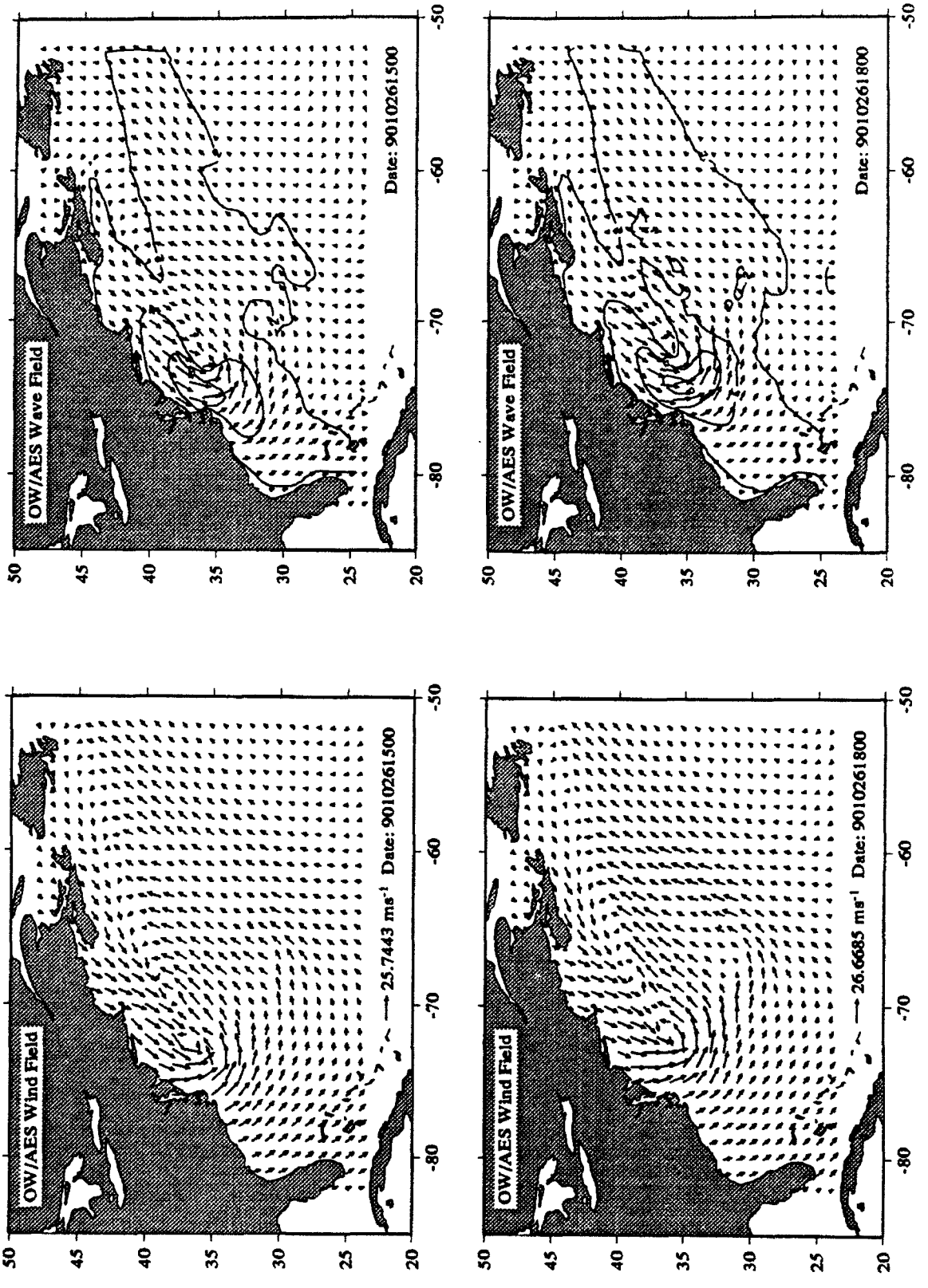

OW/AES Wind Field
17.3077 ms-1 Date: 9010260300
50
45
40
35
30
25
20
-80
-70
-60
-50


OW/AES Wave Field
Date: 9010260300
50
45
40
35
30
25
20
-80
-70
-60
-50


OW/AES Wind Field
17.7719 ms-1 Date: 9010260600
50
45
40
35
30
25
20
-80
-70
-60
-50


OW/AES Wave Field
Date: 9010260600
50
45
40
35
30
25
20
-80
-70
-60
-50

OW/AES Wave Field
Date: 9010260900
OW/AES Wave Field
Date: 9010261200
OW/AES Wind Field
20.5967 ms-1 Date: 9010260900
OW/AES Wind Field
22.4805 ms-1 Date: 9010261200
50
45
40
35
30
25
20
-50
-60
-70
-80


OW/AES Wave Field
Date: 9010261500
OW/AES Wave Field
Date: 9010261800
OW/AES Wind Field
25.7443 ms-1 Date: 9010261500
OW/AES Wind Field
26.6685 ms-1 Date: 9010261800
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-60
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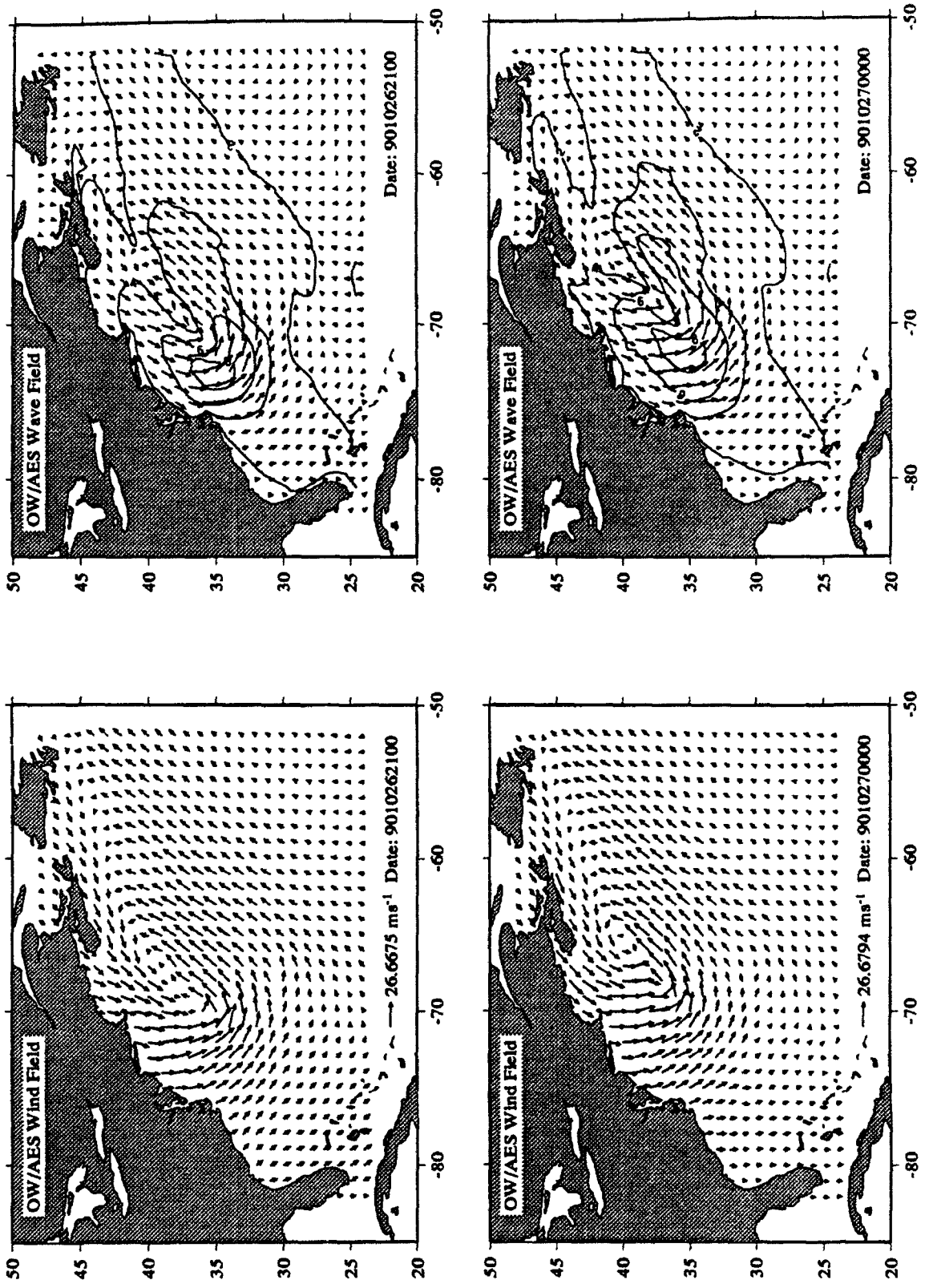
-80


OW/AES Wave Field
Date: 9010262100
OW/AES Wave Field
Date: 9010270000
OW/AES Wind Field
26.6675 ms-1 Date: 9010262100
OW/AES Wind Field
26.6794 ms-1 Date: 9010270000
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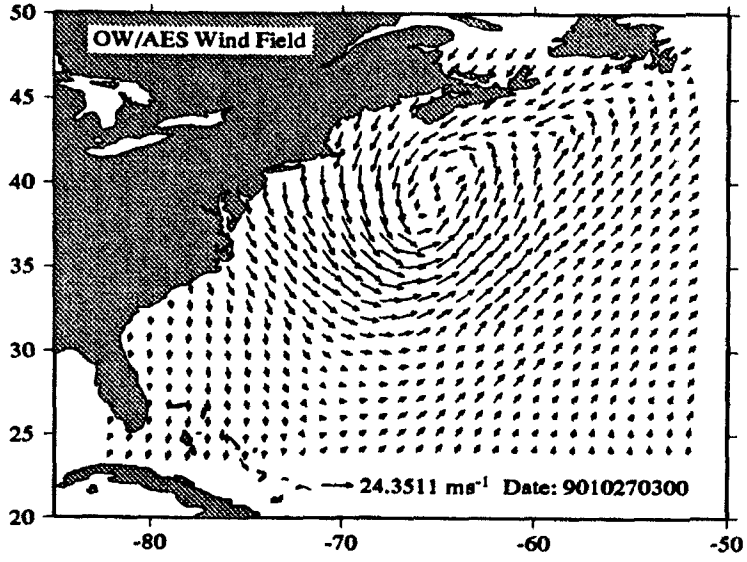
-80


OW/AES Wind Field
24.3511 ms-1 Date: 9010270300
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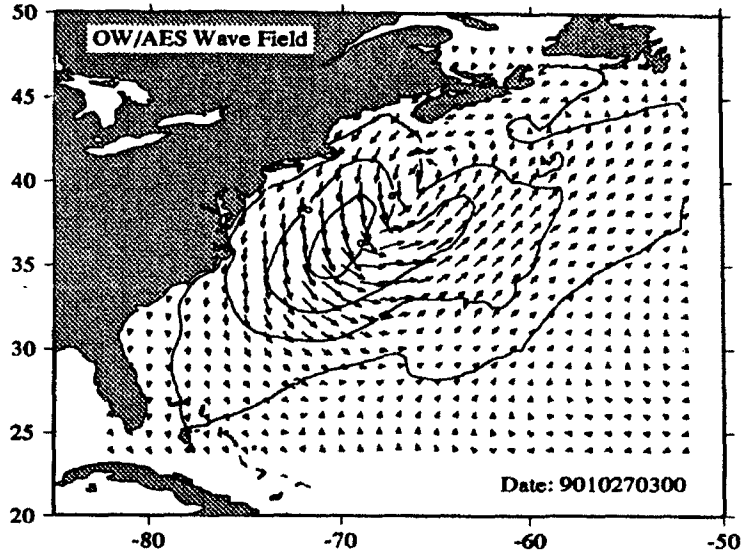
-80
-70
-60
-50


OW/AES Wave Field
Date: 9010270300
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25
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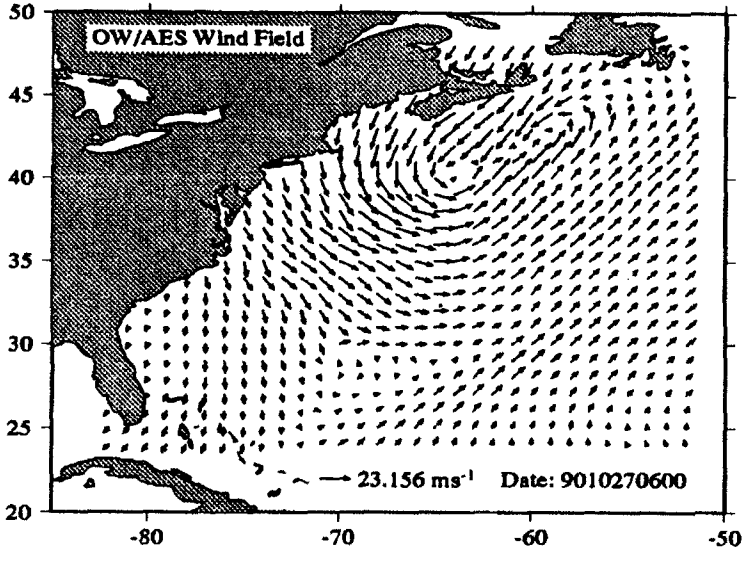
-80
-70
-60
-50


OW/AES Wind Field
23.156 ms-1 Date: 9010270600
50
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25
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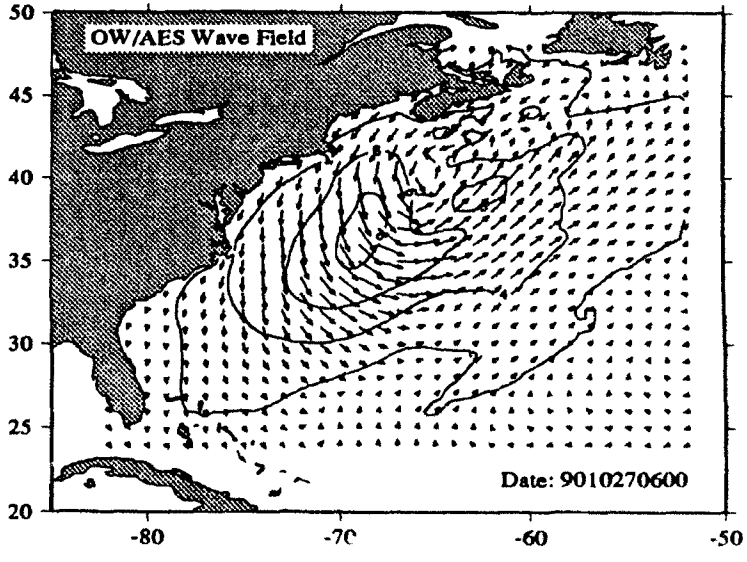
-80
-70
-60
-50


OW/AES Wave Field
Date: 9010270600
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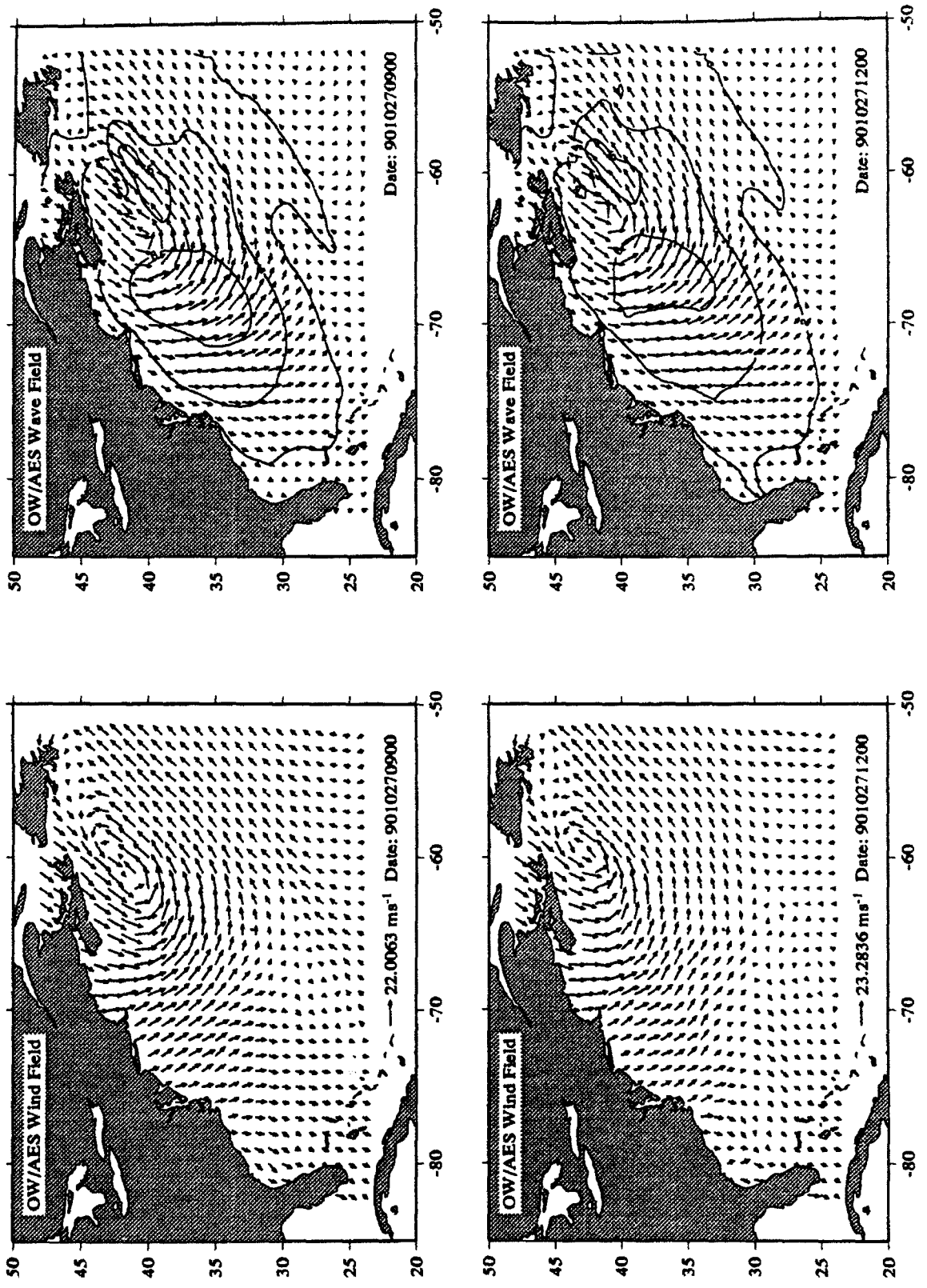
30
25
20
-80
-70
-60
-50


OW/AES Wave Field
Date: 9010270900
OW/AES Wave Field
Date: 9010271200
OW/AES Wind Field
22.0063 ms-1 Date: 9010270900
OW/AES Wind Field
23.2836 ms-1 Date: 9010271200
50
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25
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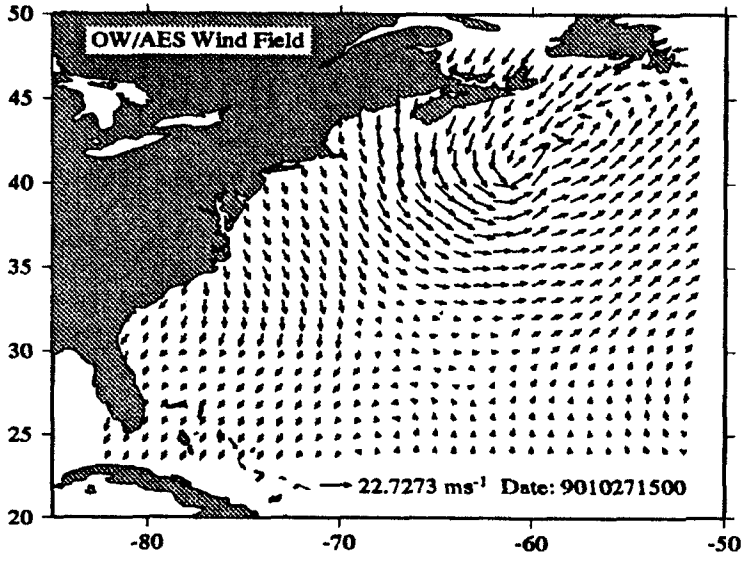
-60
-70
-80


OW/AES Wind Field
22.7273 ms-1 Date: 9010271500
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25
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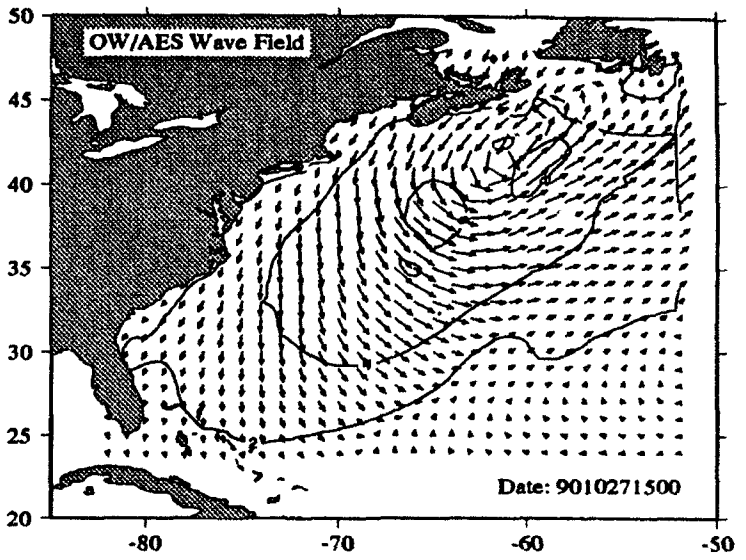
-80
-70
-60
-50


OW/AES Wave Field
Date: 9010271500
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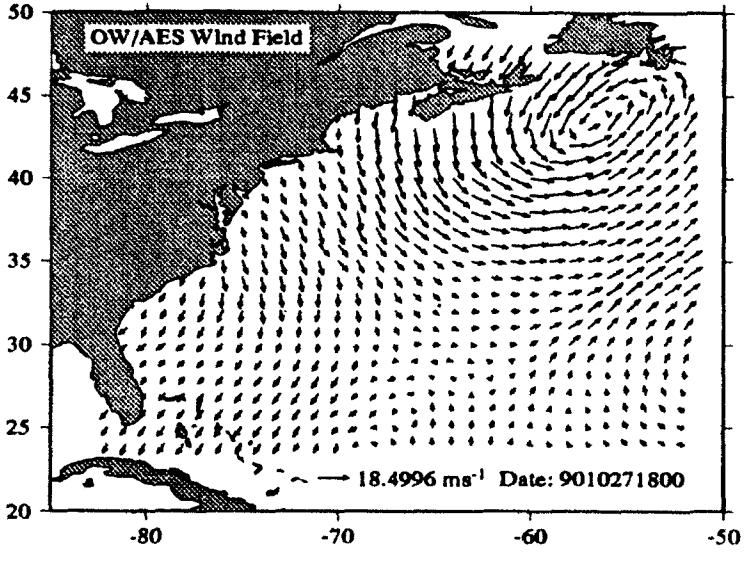
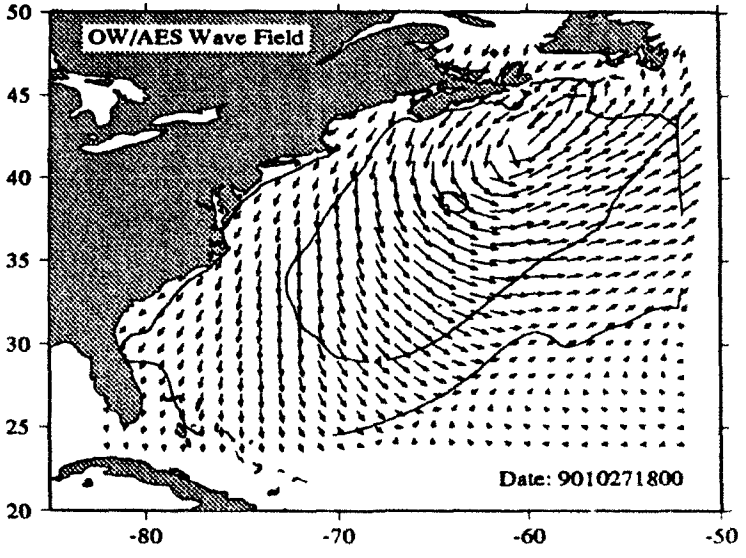
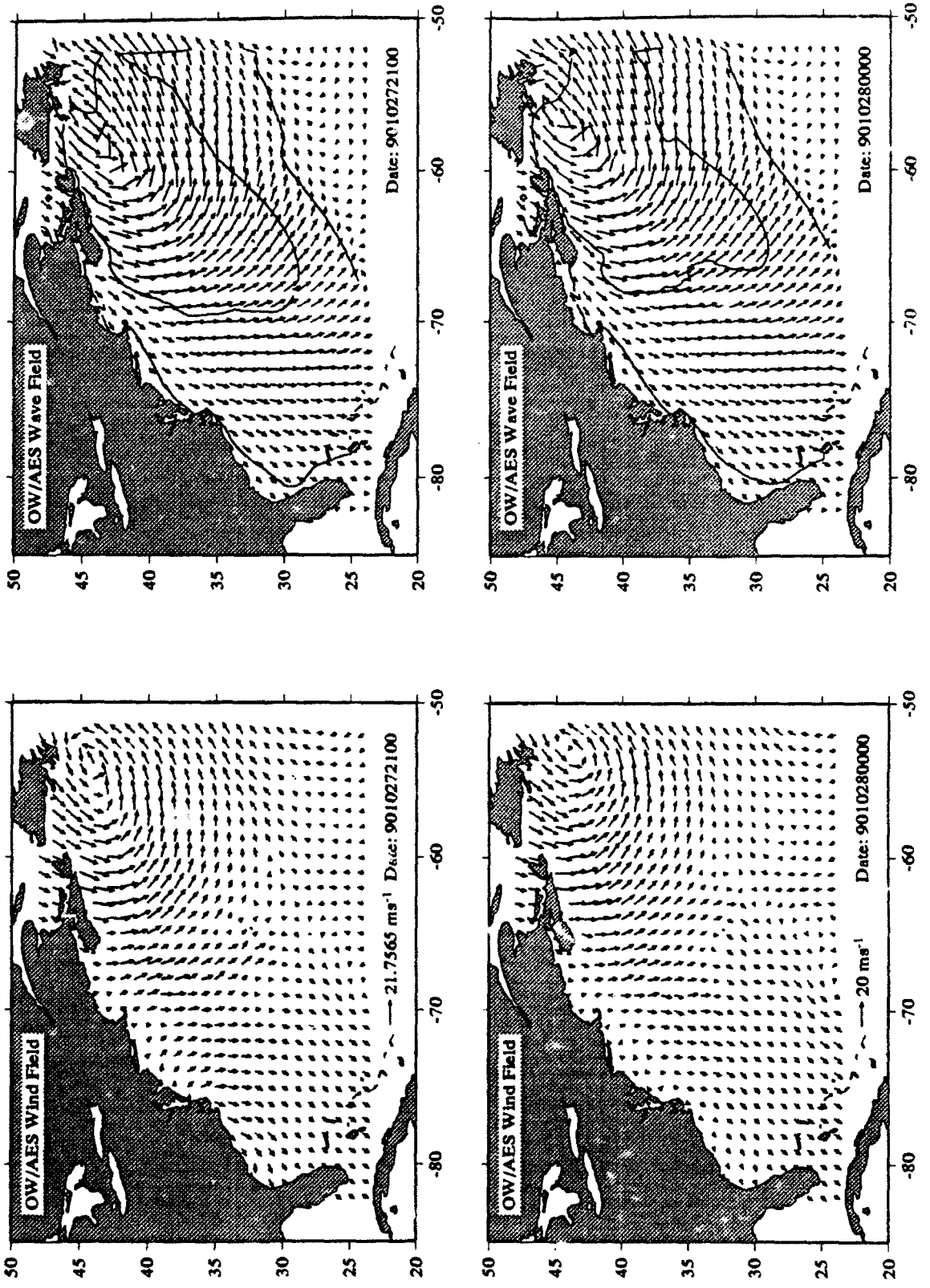
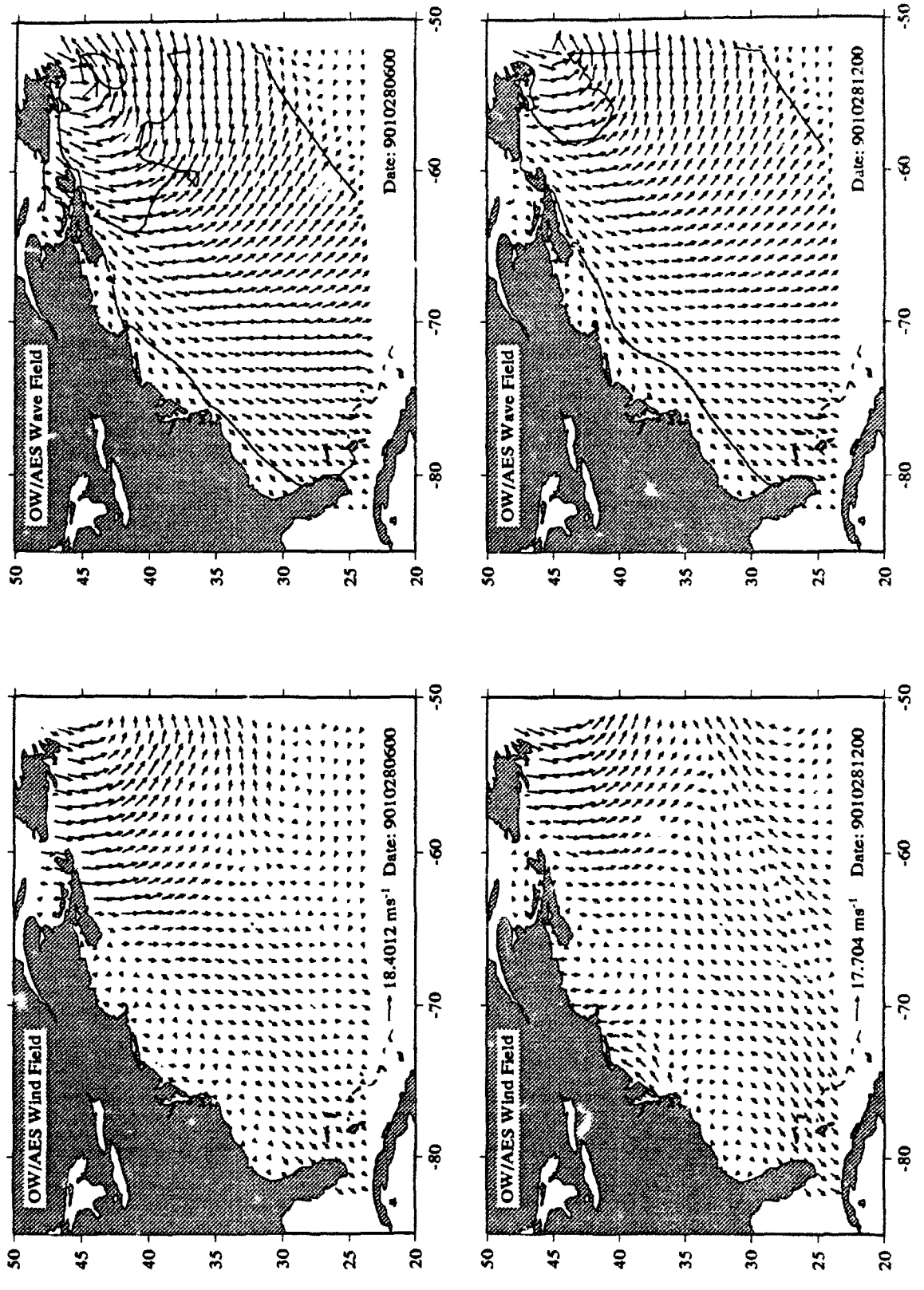
30
25
20
-80
-70
-60
-50


OW/AES Wind Field
18.4996 ms-1 Date: 9010271800
50
45
40
35
30
25
20
-80
-70
-60
-50

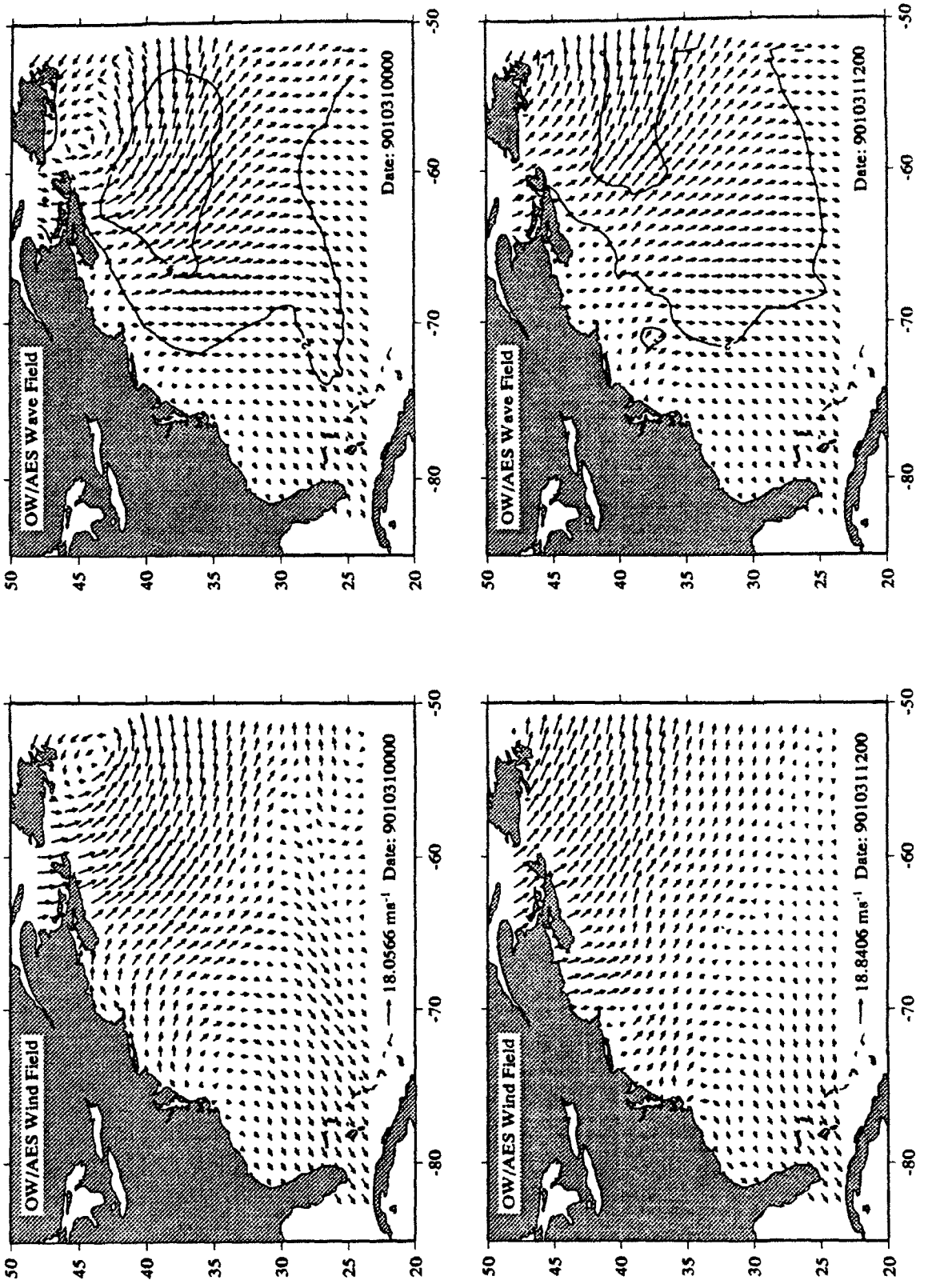

OW/AES Wave Field
Date: 9010271800
50
45
40
35
30
25
20
-80
-70
-60
-50


OW/AES Wave Field
Date: 9010272100
OW/AES Wave Field
Date: 9010280000
OW/AES Wind Field
21.7565 ms-1 Date: 9010272100
OW/AES Wind Field
20 ms-1 Date: 9010280000
50
45
40
35
30
25
20
-50
-60
-70
-80


OW/AES Wave Field
Date: 9010280600
OW/AES Wave Field
Date: 9010281200
OW/AES Wind Field
18.4012 ms-1 Date: 9010280600
OW/AES Wind Field
17.704 ms-1 Date: 9010281200
50
45
40
35
30
25
20
-50
-60
-70
-80

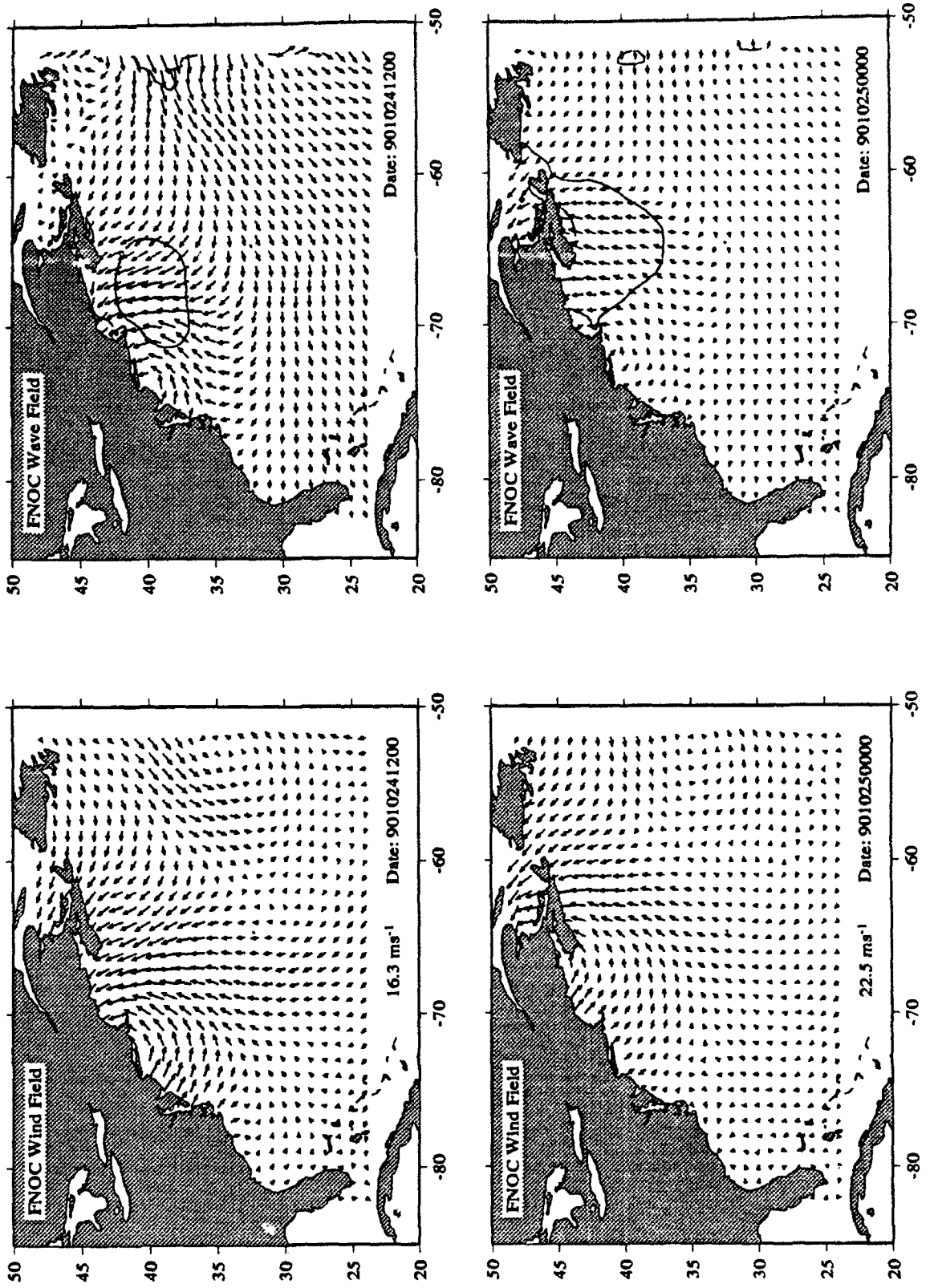
OW/AES Wind Field
17.038 ms-1
Date: 9010290000
OW/AES Wave Field
Date: 9010290000
OW/AES Wind Field
15.8759 ms-1
Date: 9010291200
OW/AES Wave Field
Date: 9010291200

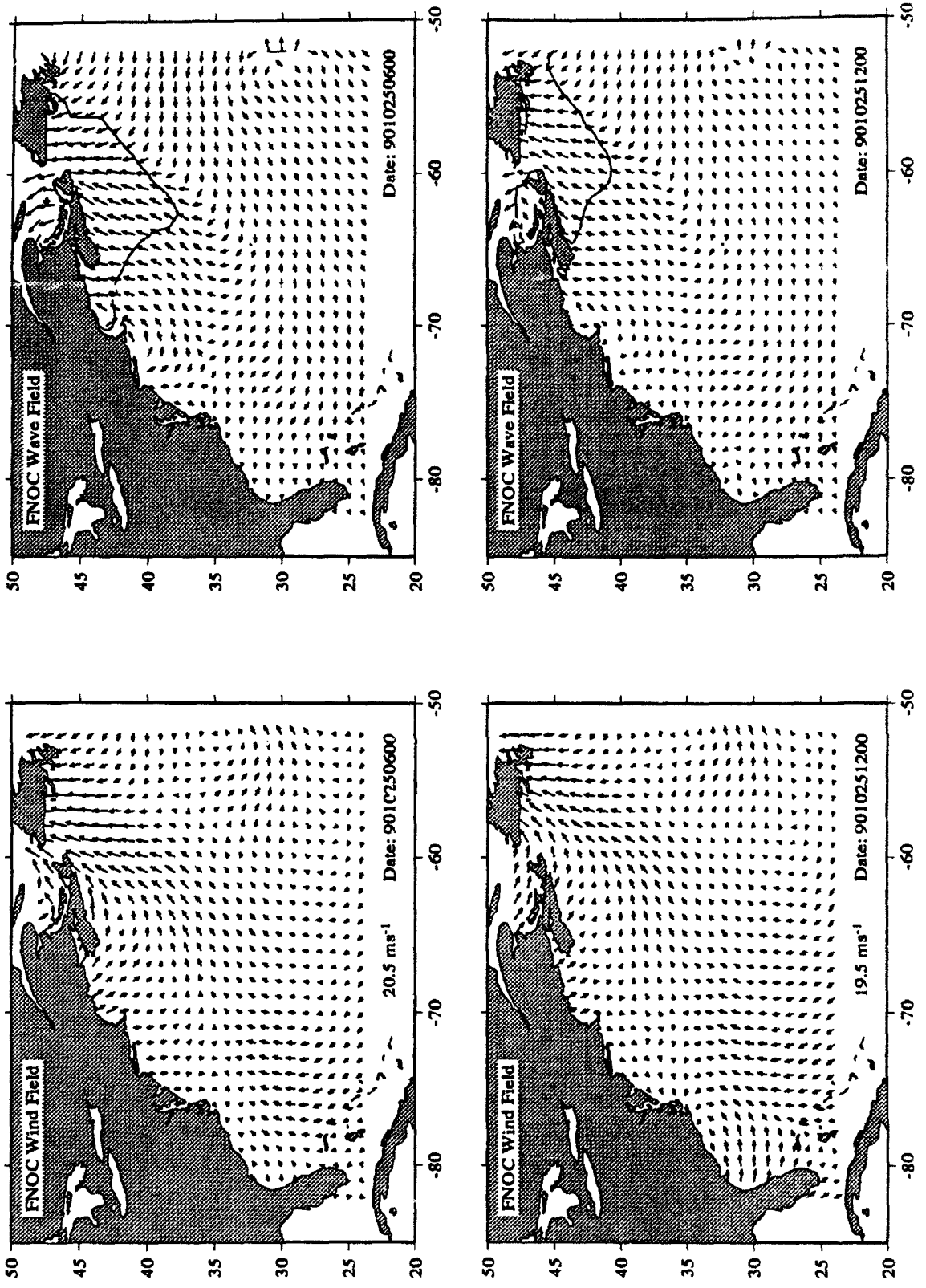
OW/AES Wave Field
Date: 9010300000
OW/AES Wave Field
Date: 9010301200
OW/AES Wind Field
21.0752 ms-1 Date: 9010300000
OW/AES Wind Field
23.3401 ms-1 Date: 9010301200
50
45
40
35
30
25
20
-50
-60
-70
-80

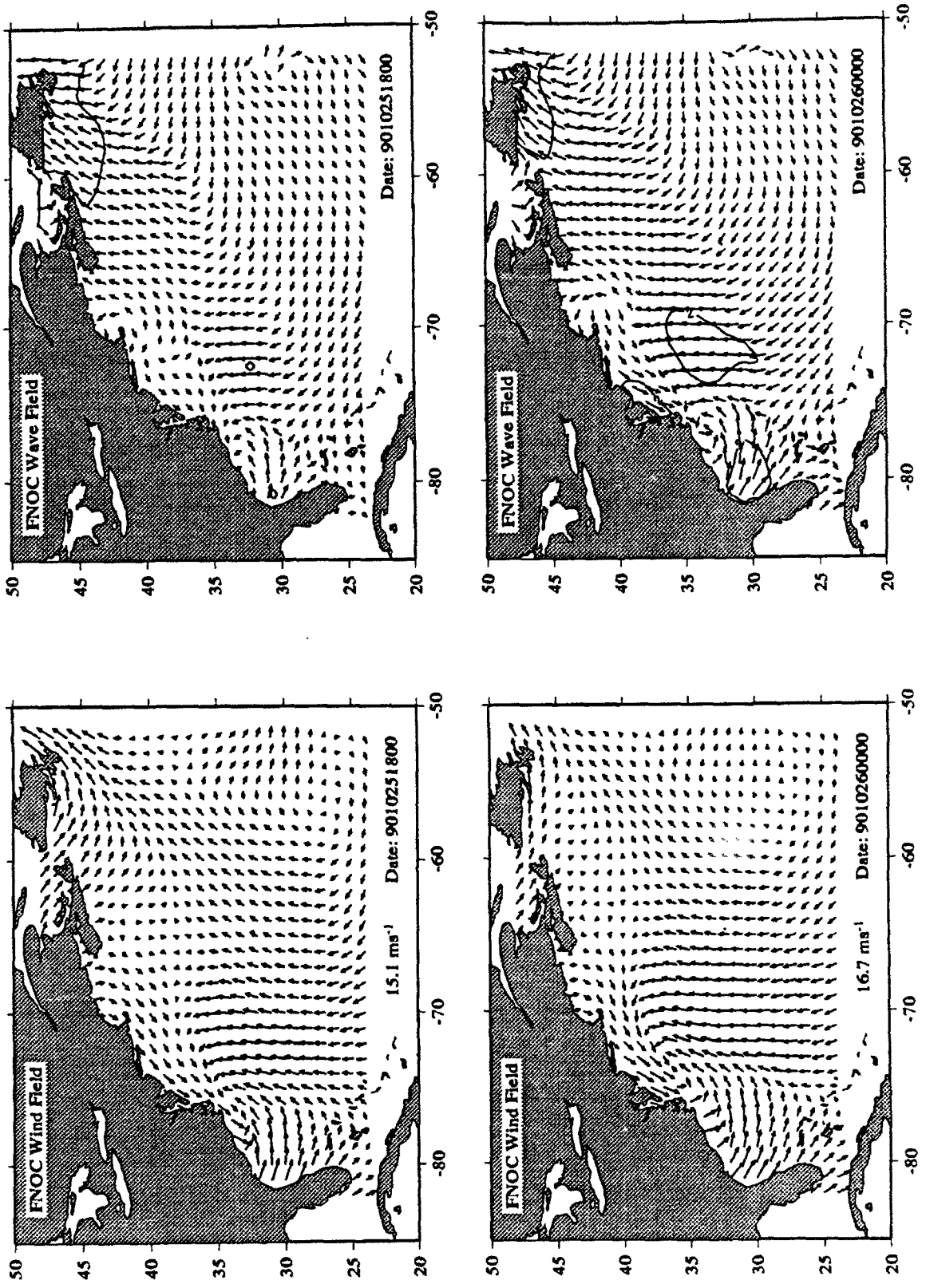

OW/AES Wave Field
Date: 9010310000
OW/AES Wave Field
Date: 9010311200
OW/AES Wind Field
18.0566 ms-1 Date: 9010310000
OW/AES Wind Field
18.8406 ms-1 Date: 9010311200
50
45
40
35
30
25
20
-50
-60
-70
-80

D.2: Fleet Numerical Oceanography Center (FNOC)

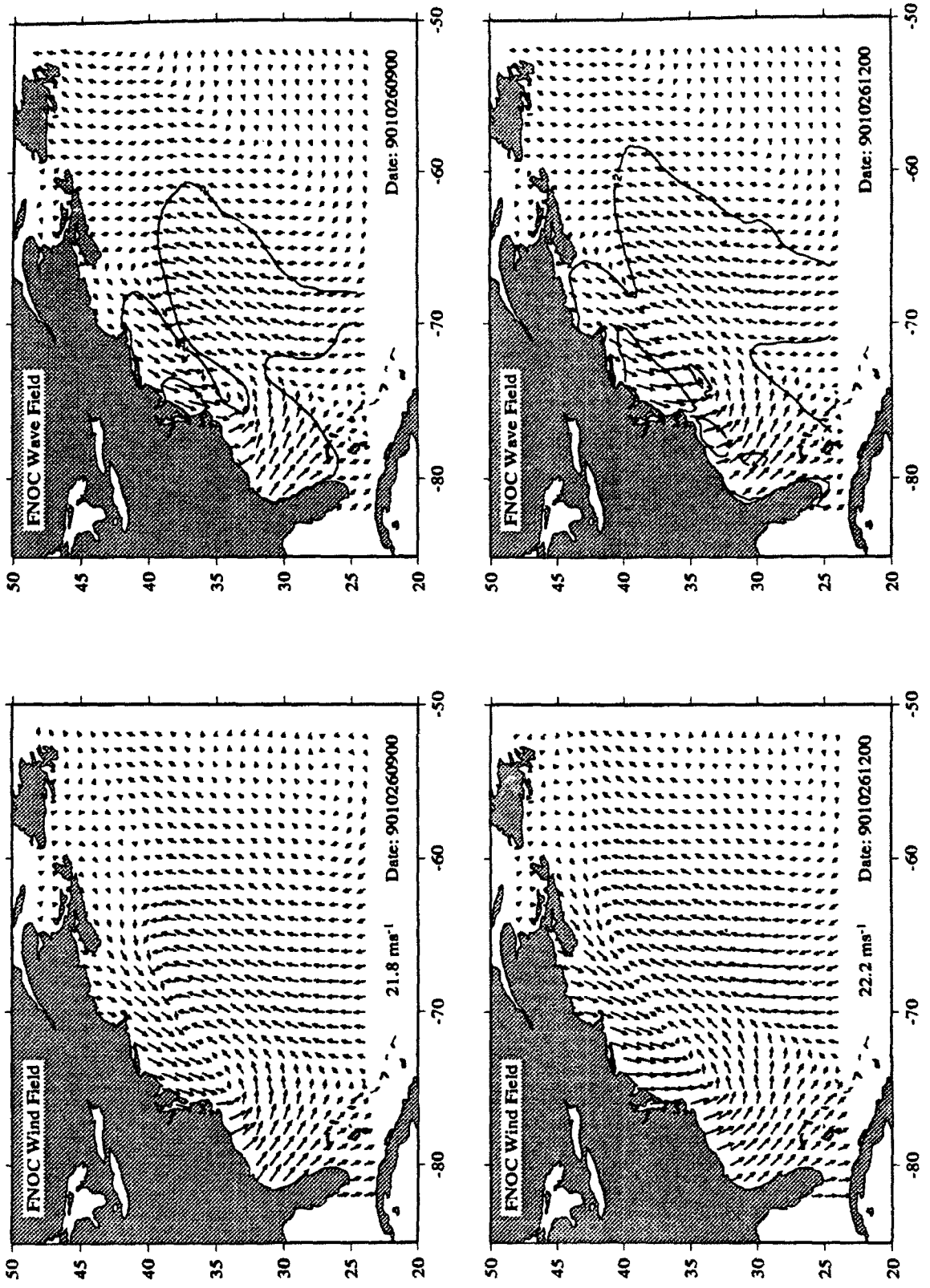
Custer diagrams are presented for the time period from 24 October 1990, 12:00 GMT to 28 October 1990, 12:00 GMT of the wind field and corresponding wave hindcasts. Note that the frequency of maps is every 3 hr from 26-28 October, which covers the major storm period.


FNOC Wave Field
Date: 9010241200
FNOC Wave Field
Date: 9010250000
FNOC Wind Field
16.3 ms-1
Date: 9010241200
FNOC Wind Field
22.5 ms-1
Date: 9010250000
50
45
40
35
30
25
20
-50
-60
-70
-80


FNOC Wave Field
Date: 9010250600
FNOC Wave Field
Date: 9010251200
FNOC Wind Field
20.5 ms-1
Date: 9010250600
FNOC Wind Field
19.5 ms-1
Date: 9010251200
50
45
40
35
30
25
20
-50
-60
-70
-80


FNOC Wave Field
Date: 9010251800
FNOC Wave Field
Date: 9010260000
FNOC Wind Field
15.1 ms-1
Date: 9010251800
FNOC Wind Field
16.7 ms-1
Date: 9010260000
50
45
40
35
30
25
20
-50
-60
-70
-80

FNOC Wave Field
Date: 90102603
FNOC Wave Field
Date: 90102606
FNOC Wind Field
16.7 ms-1
Date: 90102603
FNOC Wind Field
21.8 ms-1
Date: 90102606


FNOC Wave Field
Date: 9010260900
FNOC Wave Field
Date: 9010261200
FNOC Wind Field
21.8 ms-1
Date: 9010260900
FNOC Wind Field
22.2 ms-1
Date: 9010261200
50
45
40
35
30
25
20
-50
-60
-70
-80

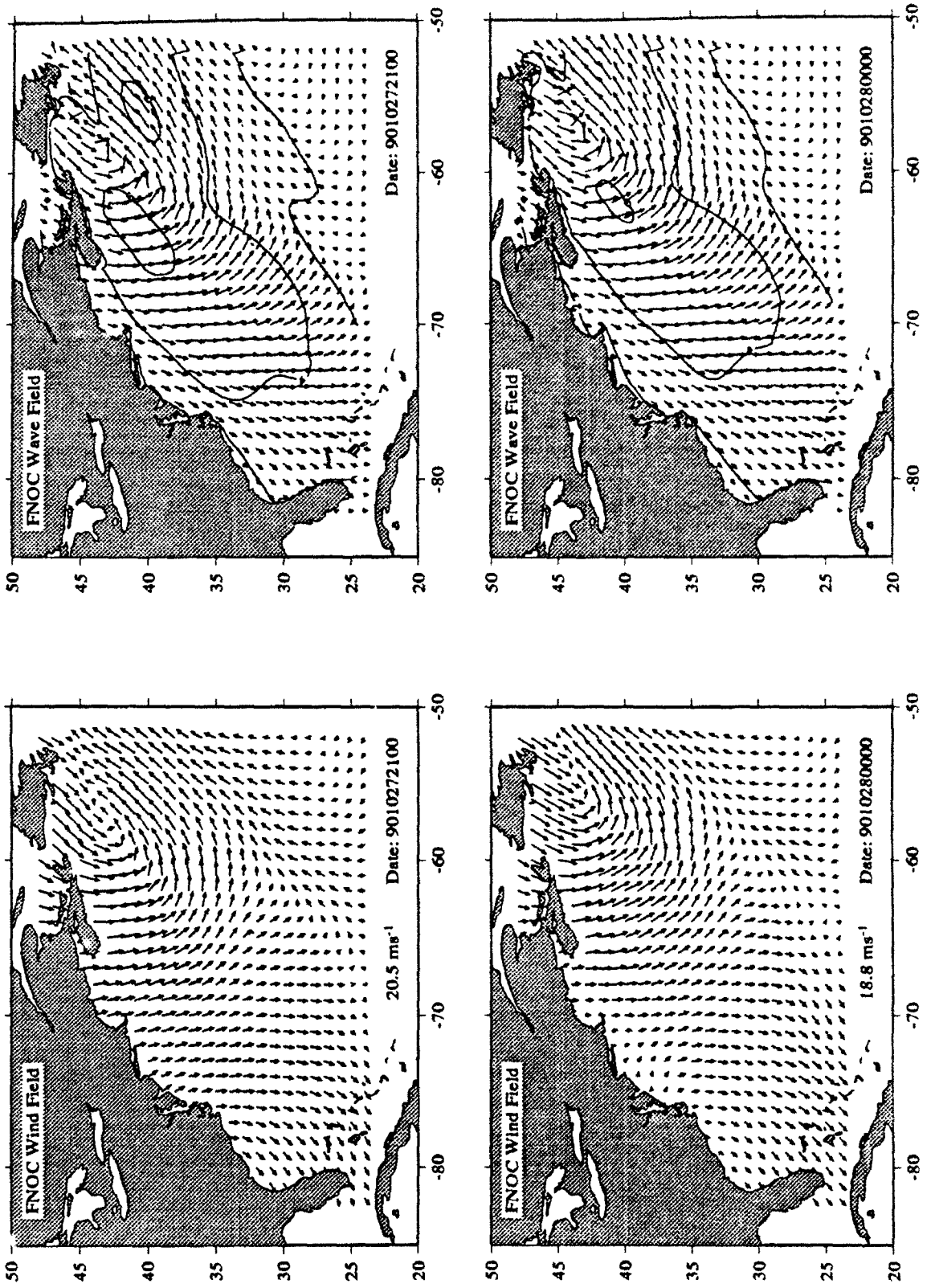
FNOC Wave Field
Date: 9010261500
FNOC Wave Field
Date: 9010261800
FNOC Wind Field
22.2 ms-1
Date: 9010261500
FNOC Wind Field
22.5 ms-1
Date: 9010261800
50
45
40
35
30
25
20
-50
-60
-70
-80

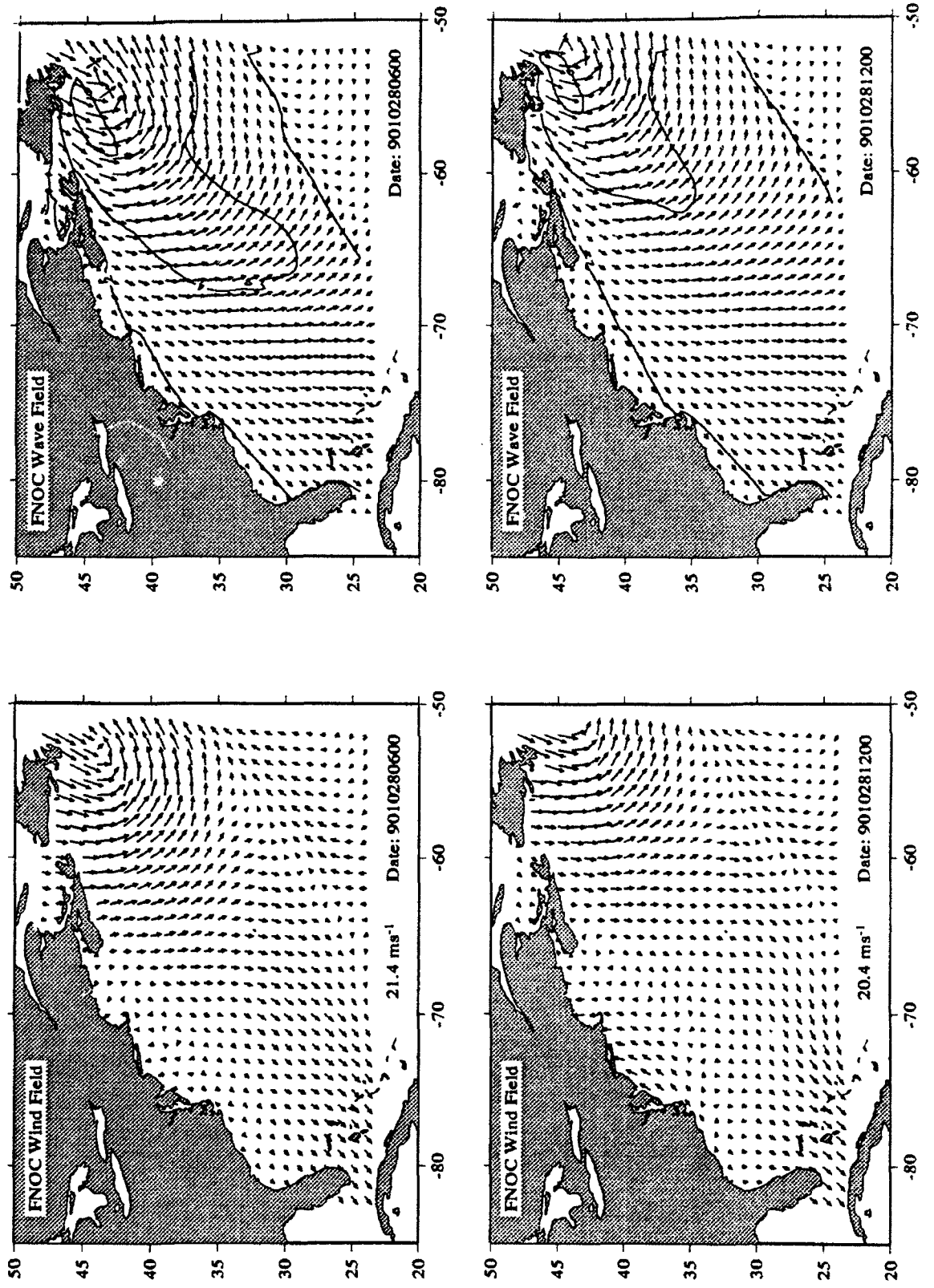
FNOC Wave Field
Date: 9010262100
FNOC Wave Field
Date: 9010270000
FNOC Wind Field
22.5 ms-1
Date: 9010262100
FNOC Wind Field
22.7 ms-1
Date: 9010270000
50
45
40
35
30
25
20
-50
-60
-70
-80

FNOC Wave Field
Date: 9010270300
FNOC Wave Field
Date: 9010270600
FNOC Wind Field
22.7 ms-1
Date: 9010270300
FNOC Wind Field
25.0 ms-1
Date: 9010270600
50
45
40
35
30
25
20
-50
-60
-70
-80

FNOC Wave Field
Date: 9010270900
FNOC Wind Field
25.0 ms-1
Date: 9010270900
FNOC Wave Field
Date: 9010271200
FNOC Wind Field
22.3 ms-1
Date: 9010271200
50
45
40
35
30
25
20
-50
-60
-70
-80

FNOC Wave Field
Date: 9010271500
FNOC Wave Field
Date: 9010271800
FNOC Wind Field
22.3 ms-1
Date: 9010271500
FNOC Wind Field
20.5 ms-1
Date: 9010271800
50
45
40
35
30
25
20
-50
-60
-70
-80

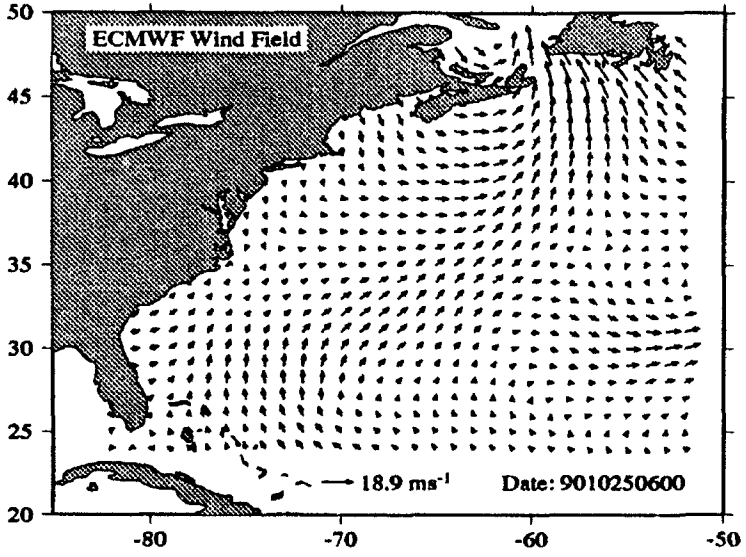

FNOC Wave Field
Date: 9010272100
FNOC Wave Field
Date: 9010280000
FNOC Wind Field
20.5 ms-1
Date: 9010272100
FNOC Wind Field
18.8 ms-1
Date: 9010280000
50
45
40
35
30
25
20
-50
-60
-70
-80

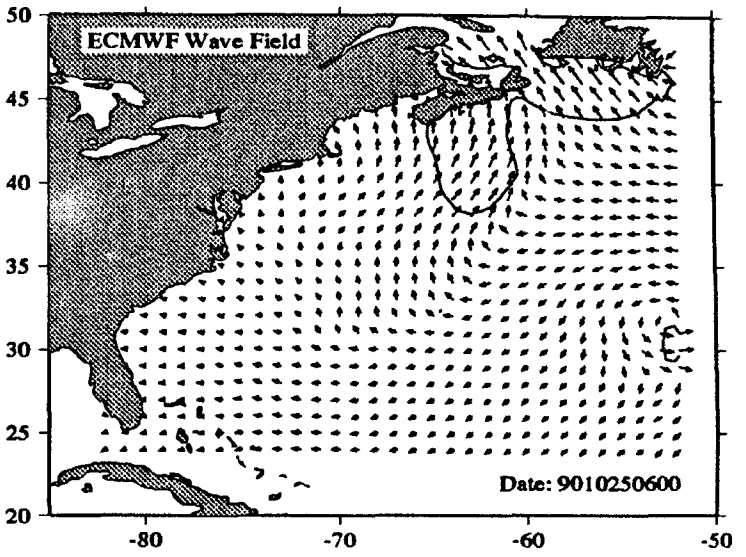

FNOC Wind Field
21.4 ms-1
Date: 9010280600
FNOC Wave Field
Date: 9010280600
FNOC Wind Field
20.4 ms-1
Date: 9010281200
FNOC Wave Field
Date: 9010281200
50
45
40
35
30
25
20
-50
-60
-70
-80

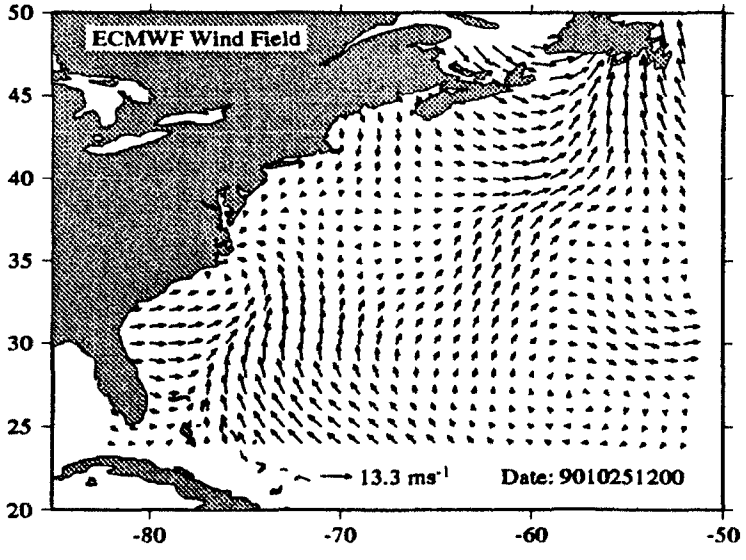
D.3: European Centre for Medium-Range Weather Forecasts (ECMWF)

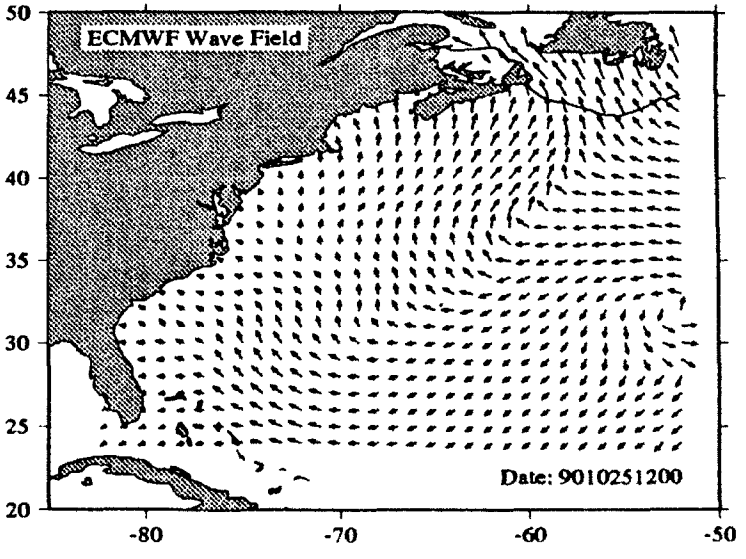
Custer diagrams are presented for the time period from 24 October 1990, 12:00 GMT to 28 October 1990, 12:00 GMT of the wind field and corresponding wave hindcasts. Note that the frequency of maps is every 3 hr from 26-28 October, which covers the major storm period.

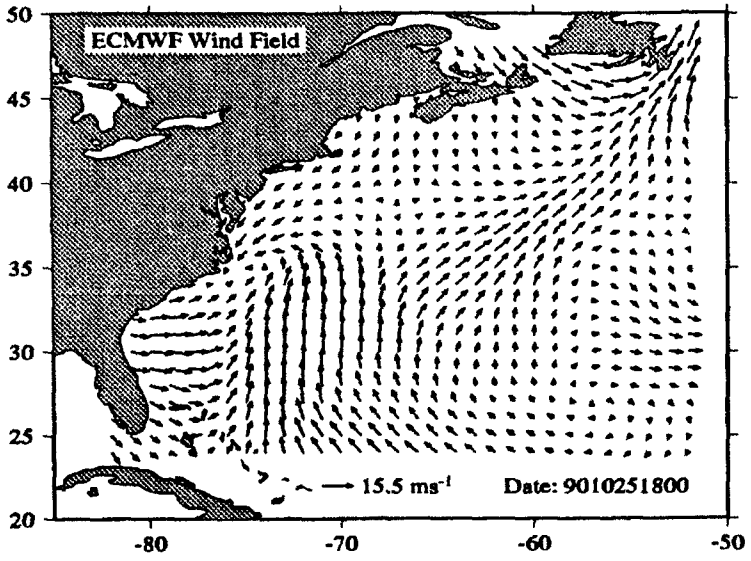
ECMWF Wind Field
13.0 ms-1
Date: 9010241200
ECMWF Wave Field
Date: 9010241200
ECMWF Wind Field
17.4 ms-1
Date: 9010250000
ECMWF Wave Field
Date: 9010250000
50
45
40
35
30
25
20
-50
-60
-70
-80

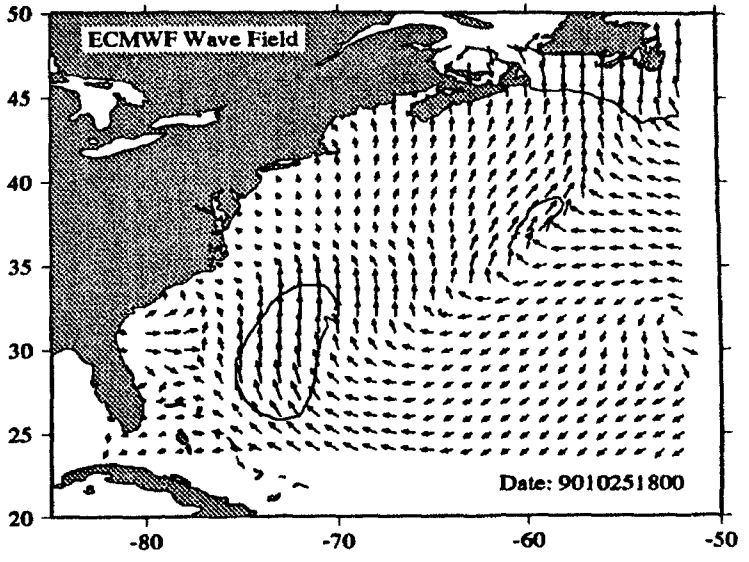

ECMWF Wind Field
18.9 ms-1
Date: 9010250600
50
45
40
35
30
25
20
-80
-70
-60
-50

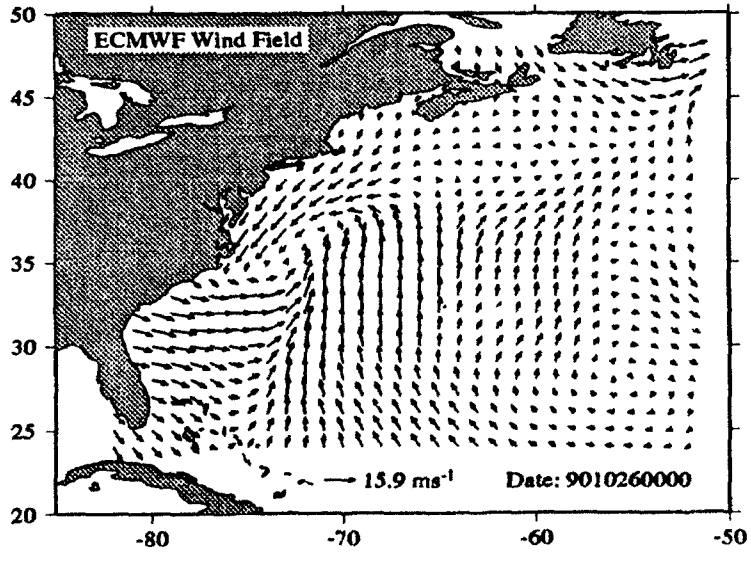

ECMWF Wave Field
Date: 9010250600
50
45
40
35
30
25
20
-80
-70
-60
-50

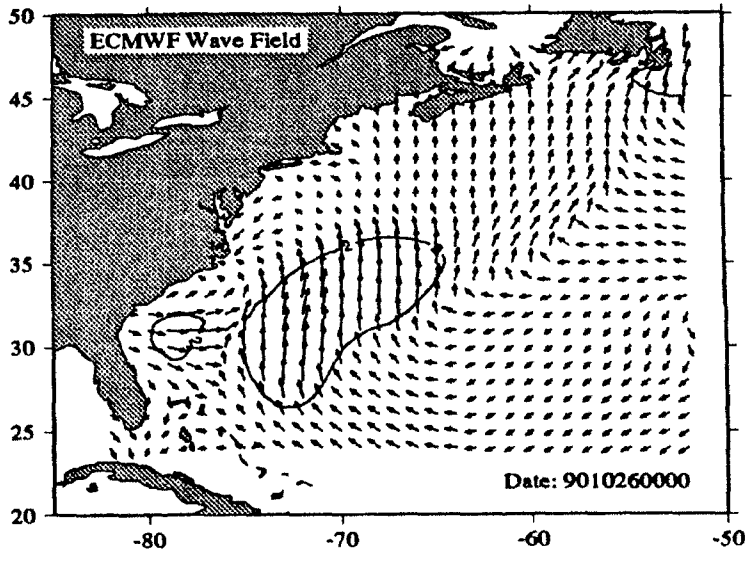

ECMWF Wind Field
13.3 ms-1
Date: 9010251200
50
45
40
35
30
25
20
-80
-70
-60
-50

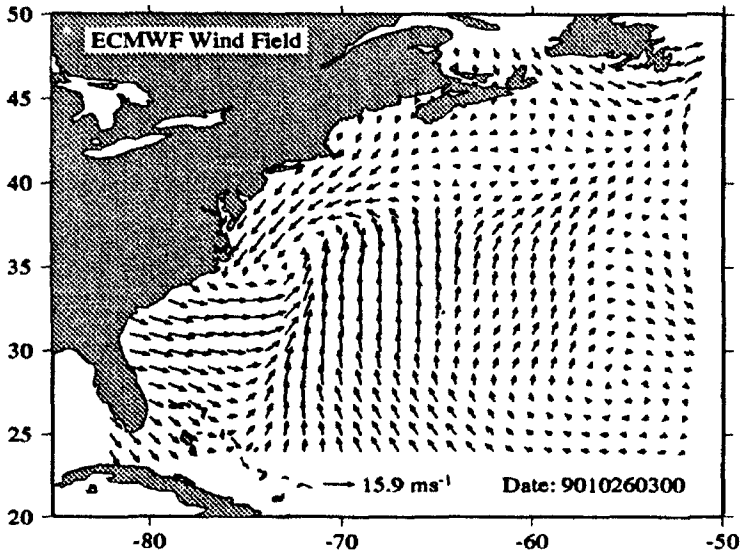

ECMWF Wave Field
Date: 9010251200
50
45
40
35
30
25
20
-80
-70
-60
-50


ECMWF Wind Field
15.5 ms-1
Date: 9010251800
50
45
40
35
30
25
20
-80
-70
-60
-50


ECMWF Wave Field
Date: 9010251800
50
45
40
35
30
25
20
-80
-70
-60
-50


ECMWF Wind Field
15.9 ms-1
Date: 9010260000
50
45
40
35
30
25
20
-80
-70
-60
-50


ECMWF Wave Field
Date: 9010260000
50
45
40
35
30
25
20
-80
-70
-60
-50


ECMWF Wind Field
15.9 ms-1
Date: 9010260300
50
45
40
35
30
25
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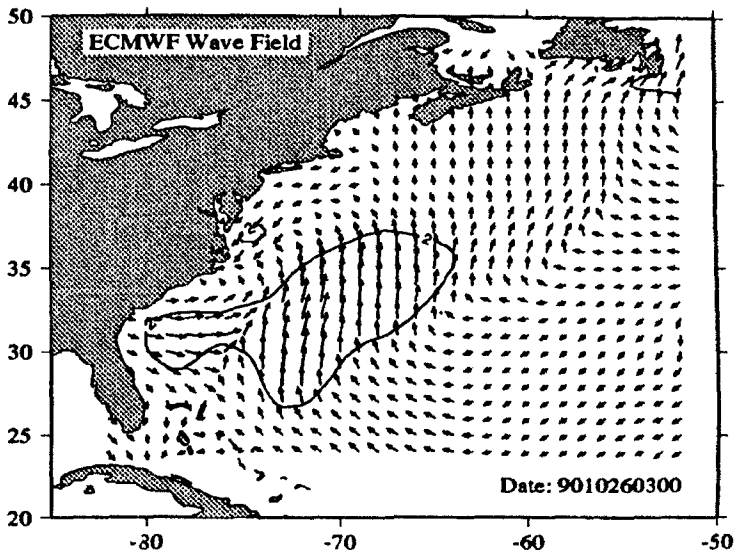
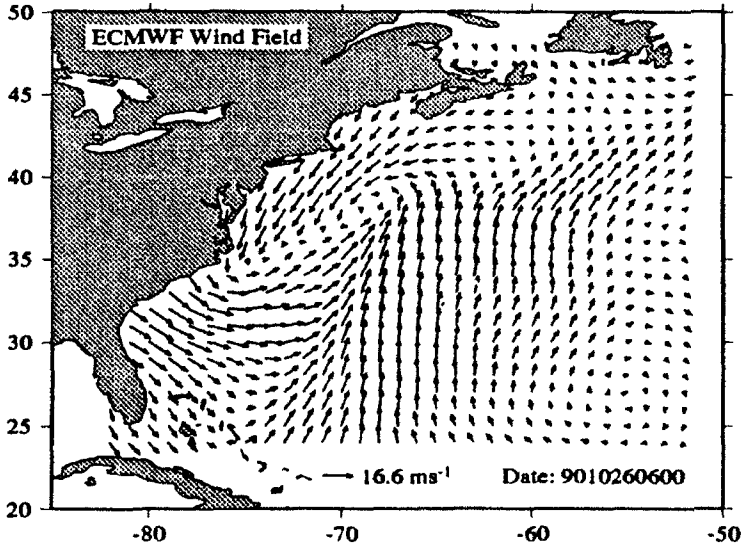
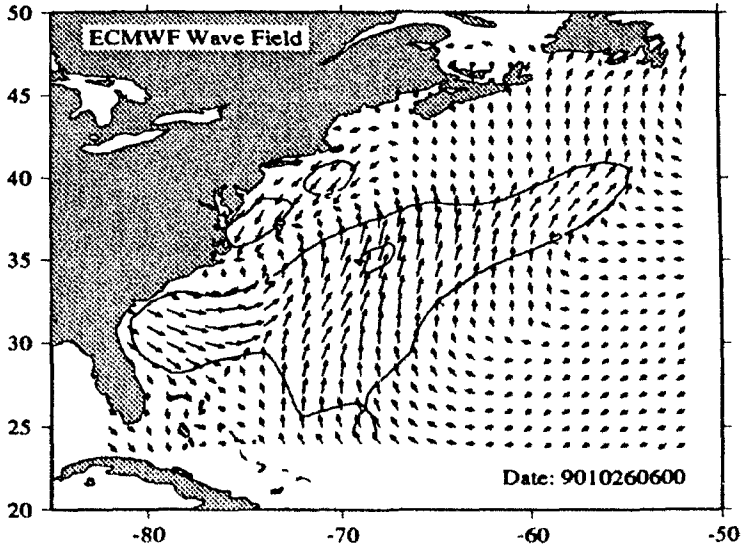
-80
-70
-60
-50


ECMWF Wave Field
Date: 9010260300
50
45
40
35
30
25
20
-80
-70
-60
-50


ECMWF Wind Field
16.6 ms-1
Date: 9010260600
50
45
40
35
30
25
20
-80
-70
-60
-50


ECMWF Wave Field
Date: 9010260600
50
45
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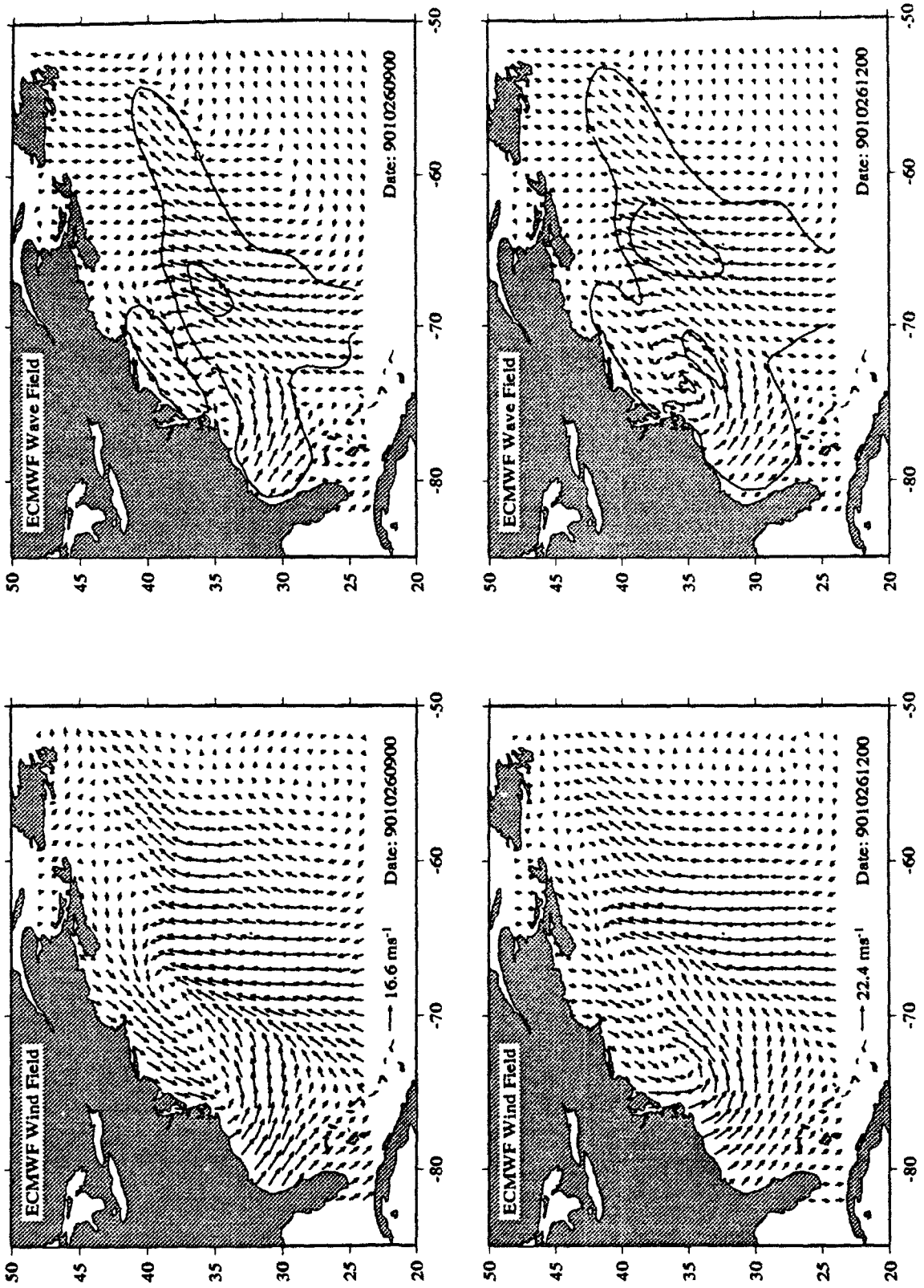
30
25
20
-80
-70
-60
-50


ECMWF Wave Field
Date: 9010260900
ECMWF Wave Field
Date: 9010261200
ECMWF Wind Field
Date: 9010260900
16.6 ms-1
ECMWF Wind Field
Date: 9010261200
22.4 ms-1
50
45
40
35
30
25
20
-50
-60
-70
-80

ECMWF Wave Field
Date: 9010261500
ECMWF Wave Field
Date: 9010261800
ECMWF Wind Field
Date: 9010261500
22.3 ms-1
ECMWF Wind Field
Date: 9010261800
21.9 ms-1
50
45
40
35
30
25
20
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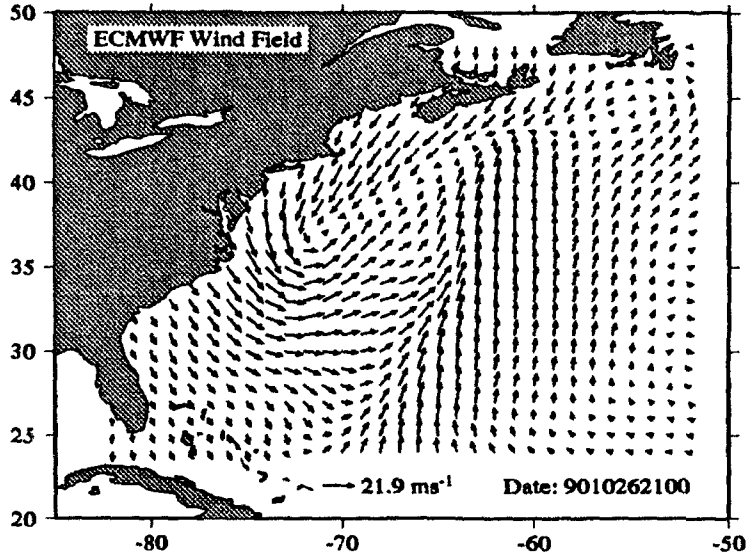
-80


ECMWF Wind Field
21.9 ms-1
Date: 9010262100
50
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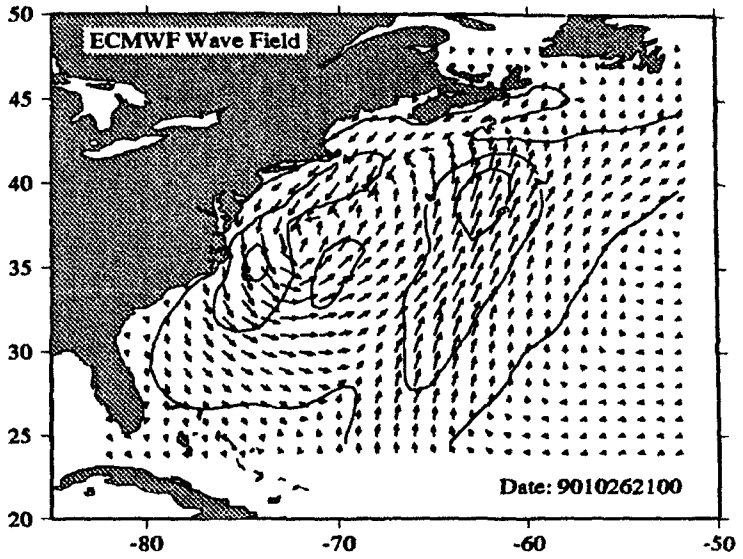
30
25
20
-80
-70
-60
-50


ECMWF Wave Field
Date: 9010262100
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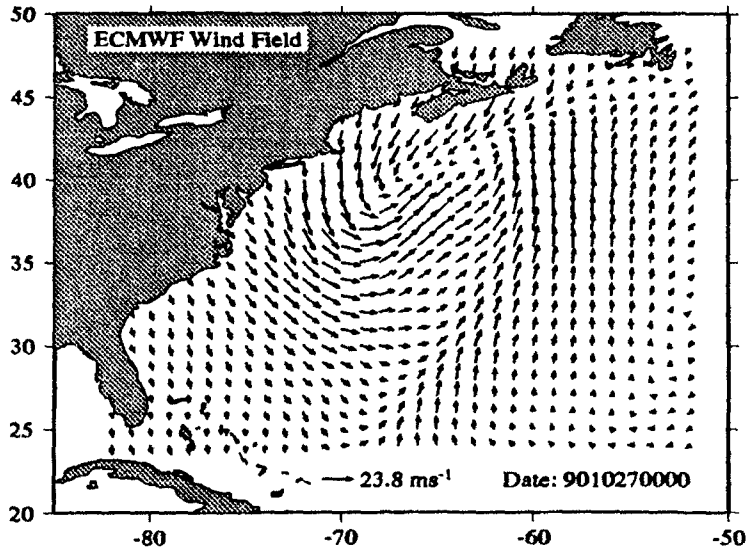
30
25
20
-80
-70
-60
-50


ECMWF Wind Field
23.8 ms-1
Date: 9010270000
50
45
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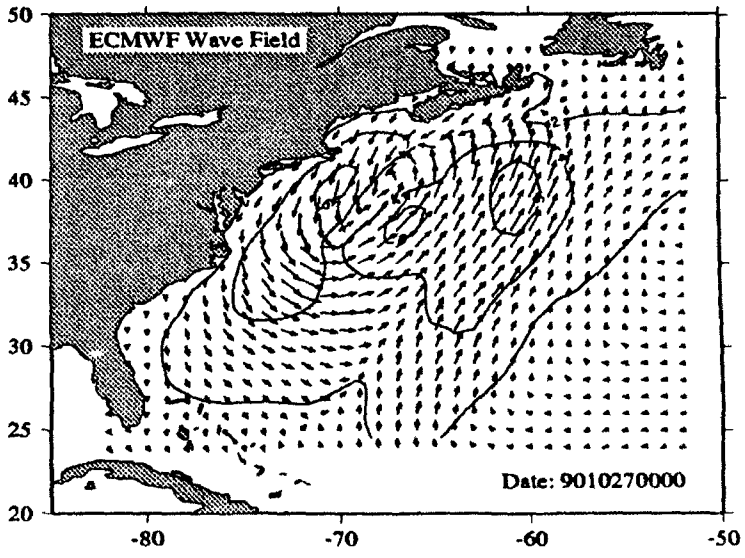
35
30
25
20
-80
-70
-60
-50


ECMWF Wave Field
Date: 9010270000
50
45
40
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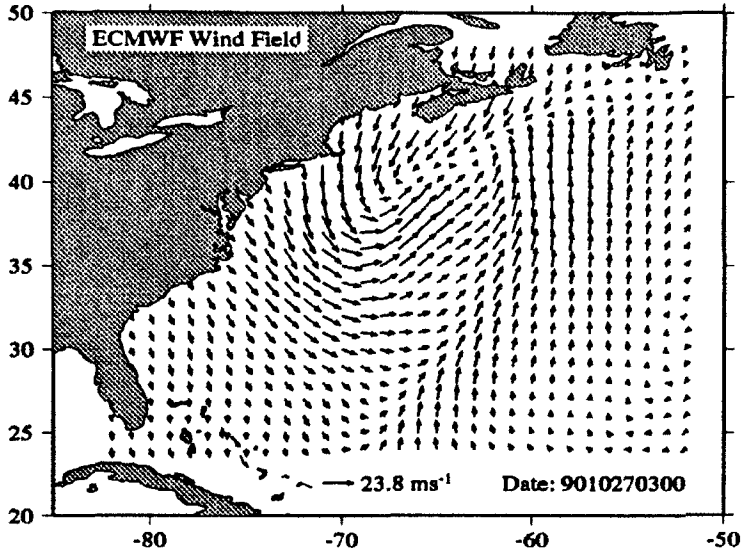
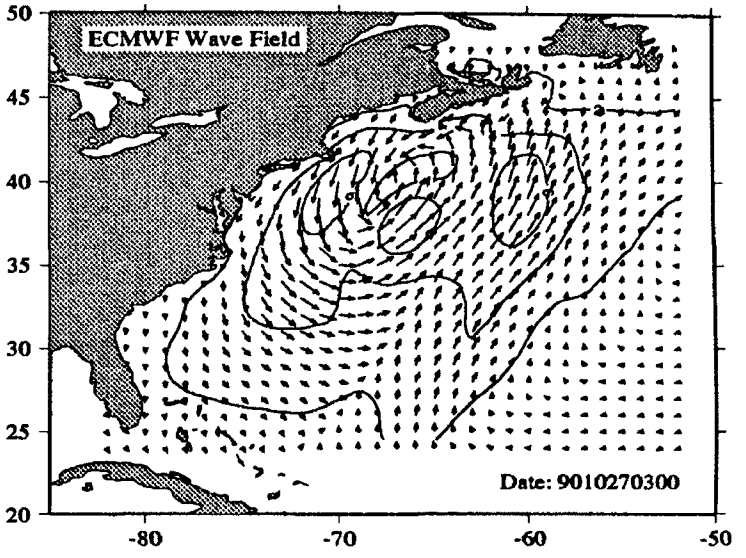
30
25
20
-80
-70
-60
-50


ECMWF Wind Field
23.8 ms-1
Date: 9010270300
50
45
40
35
30
25
20
-80
-70
-60
-50


ECMWF Wave Field
Date: 9010270300
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45
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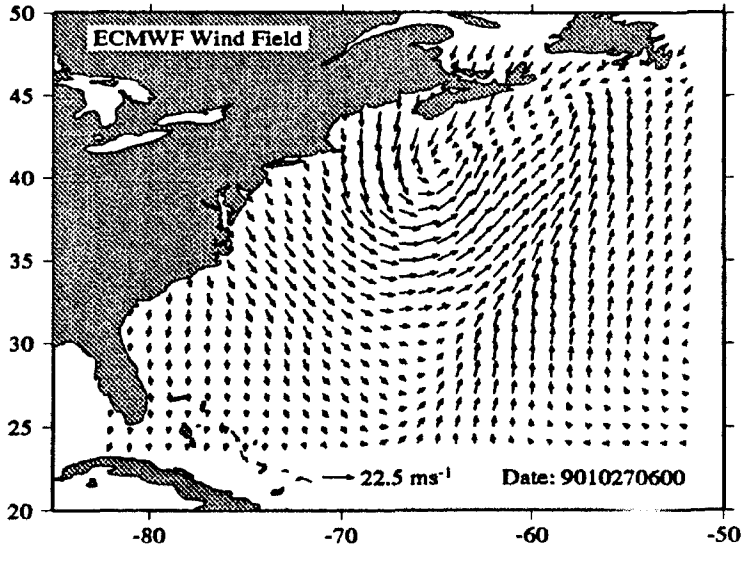
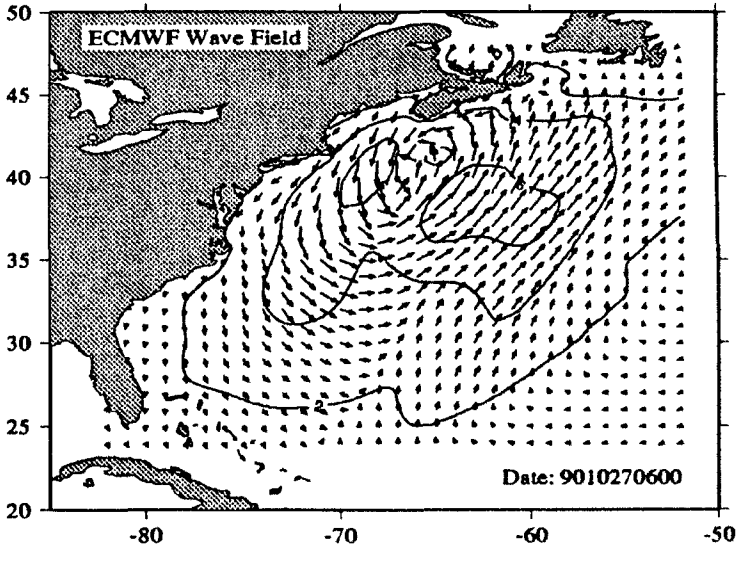
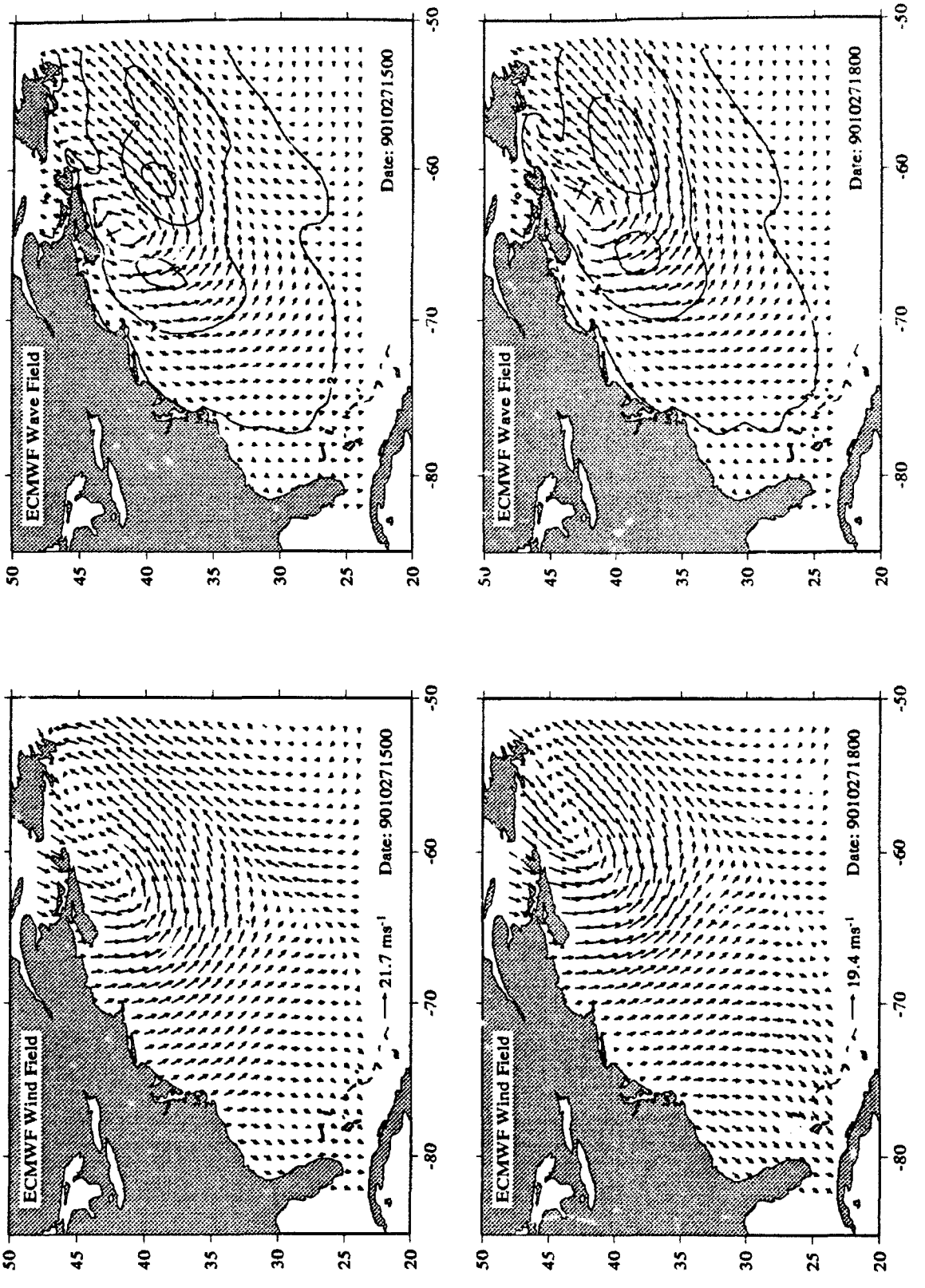
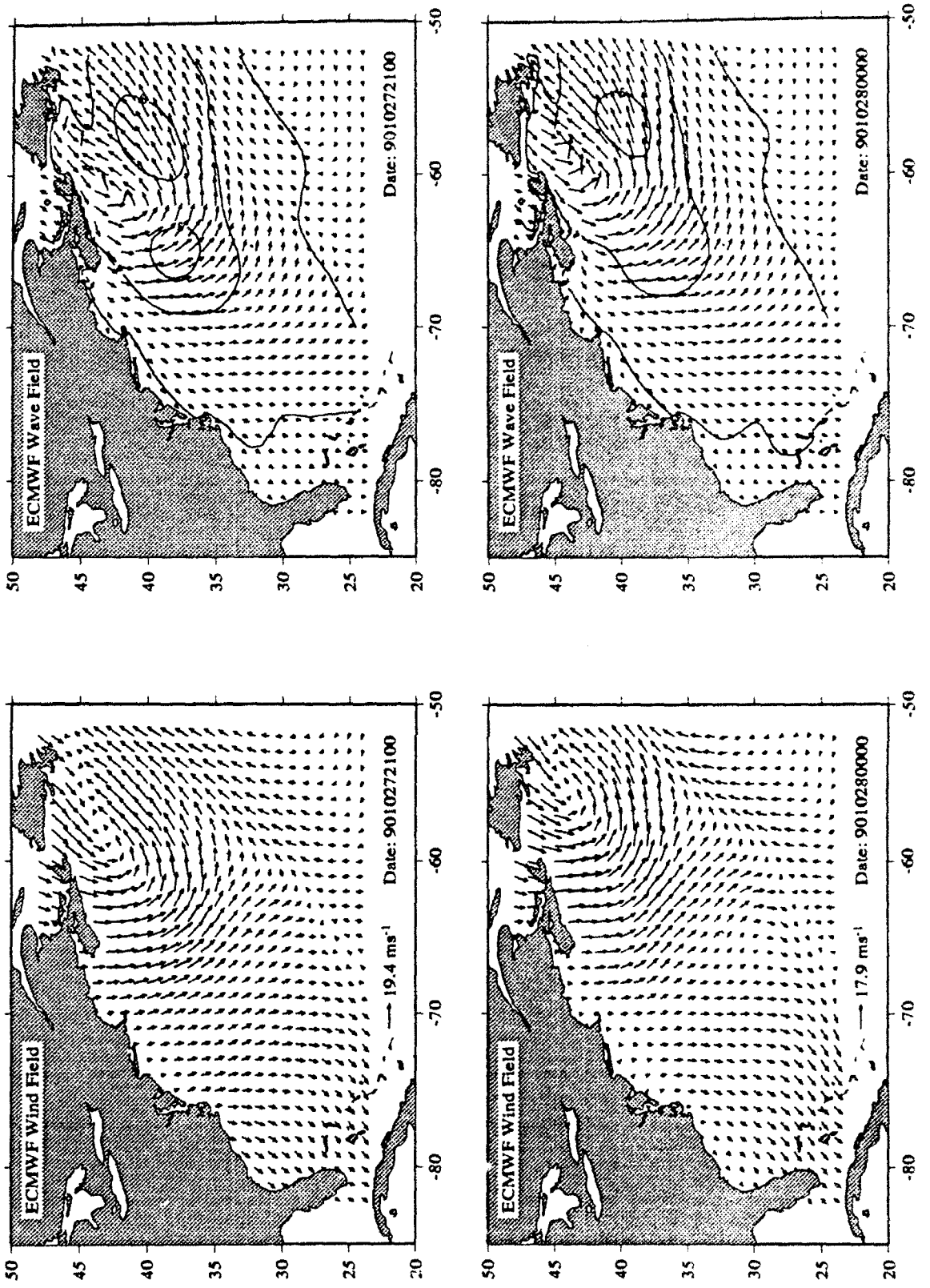
35
30
25
20
-80
-70
-60
-50

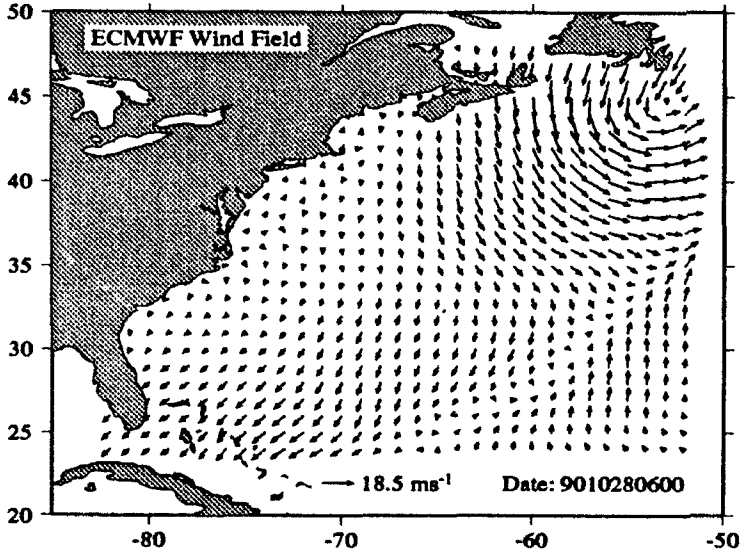

ECMWF Wind Field
22.5 ms-1
Date: 9010270600
50
45
40
35
30
25
20
-80
-70
-60
-50

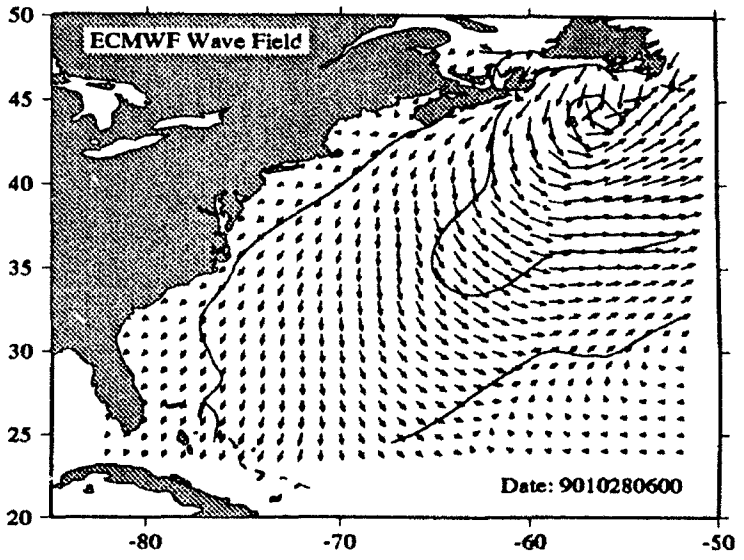

ECMWF Wave Field
Date: 9010270600
50
45
40
35
30
25
20
-80
-70
-60
-50

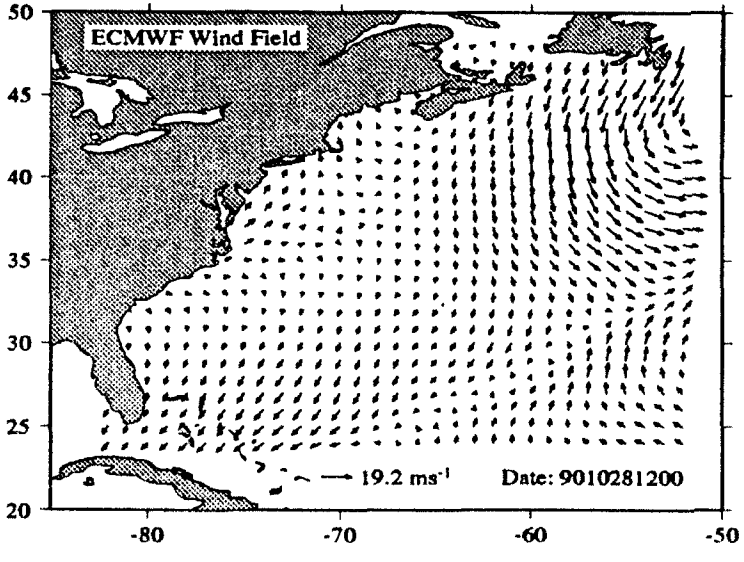
ECMWF Wave Field
Date: 9010270900
ECMWF Wave Field
Date: 9010271200
ECMWF Wind Field
22.5 ms-1
Date: 9010270900
FCMWF Wind Field
21.7 ms-1
Date: 9010271200
50
45
40
35
30
25
20
-50
-60
-70
-80

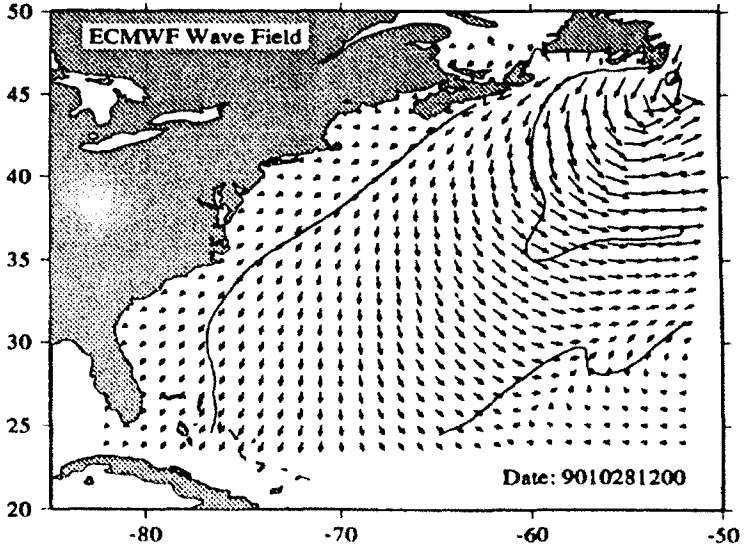

ECMWF Wave Field
Date: 9010271500
ECMWF Wave Field
Date: 9010271800
ECMWF Wind Field
21.7 ms-1
Date: 9010271500
ECMWF Wind Field
19.4 ms-1
Date: 9010271800
50
45
40
35
30
25
20
-50
-60
-70
-80


ECMWF Wave Field
Date: 9010272100
ECMWF Wave Field
Date: 9010280000
ECMWF Wind Field
19.4 ms-1
Date: 9010272100
ECMWF Wind Field
17.9 ms-1
Date: 9010280000
50
45
40
35
30
25
20
-50
-60
-70
-80


ECMWF Wind Field
18.5 ms-1
Date: 9010280600
50
45
40
35
30
25
20
-80
-70
-60
-50


ECMWF Wave Field
Date: 9010280600
50
45
40
35
30
25
20
-80
-70
-60
-50

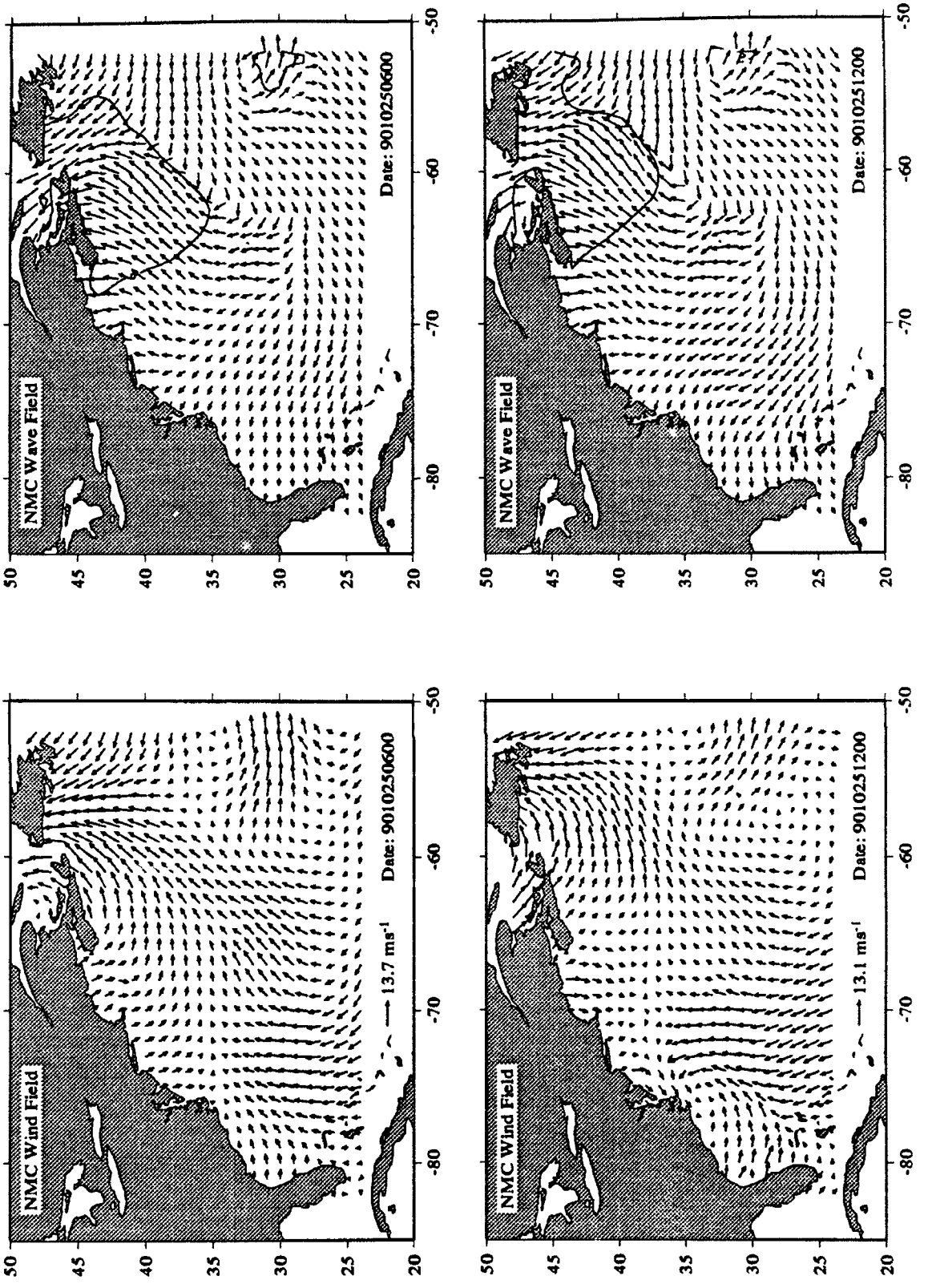

ECMWF Wind Field
19.2 ms-1
Date: 9010281200
50
45
40
35
30
25
20
-80
-70
-60
-50

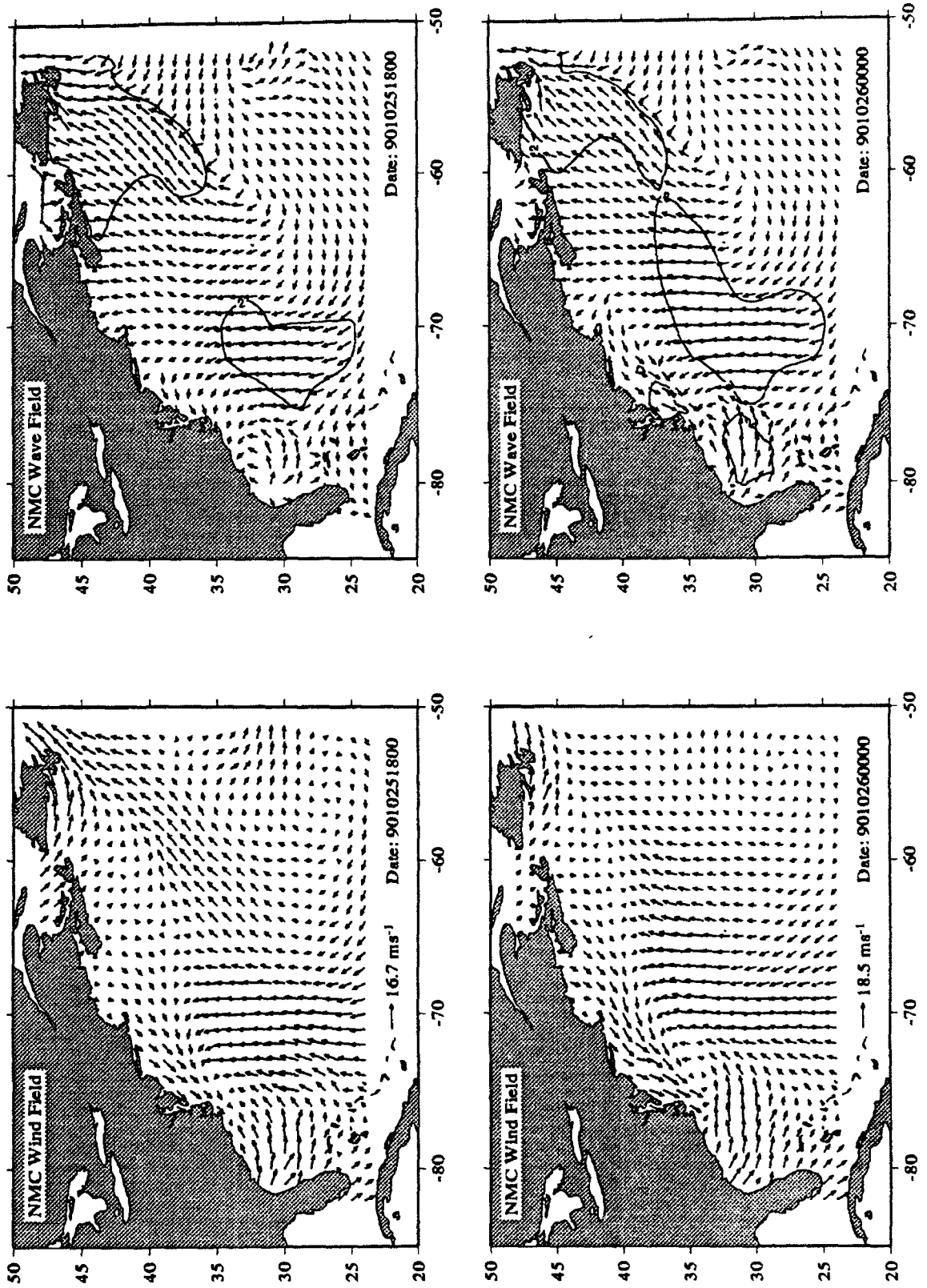

ECMWF Wave Field
Date: 9010281200
50
45
40
35
30
25
20
-80
-70
-60
-50

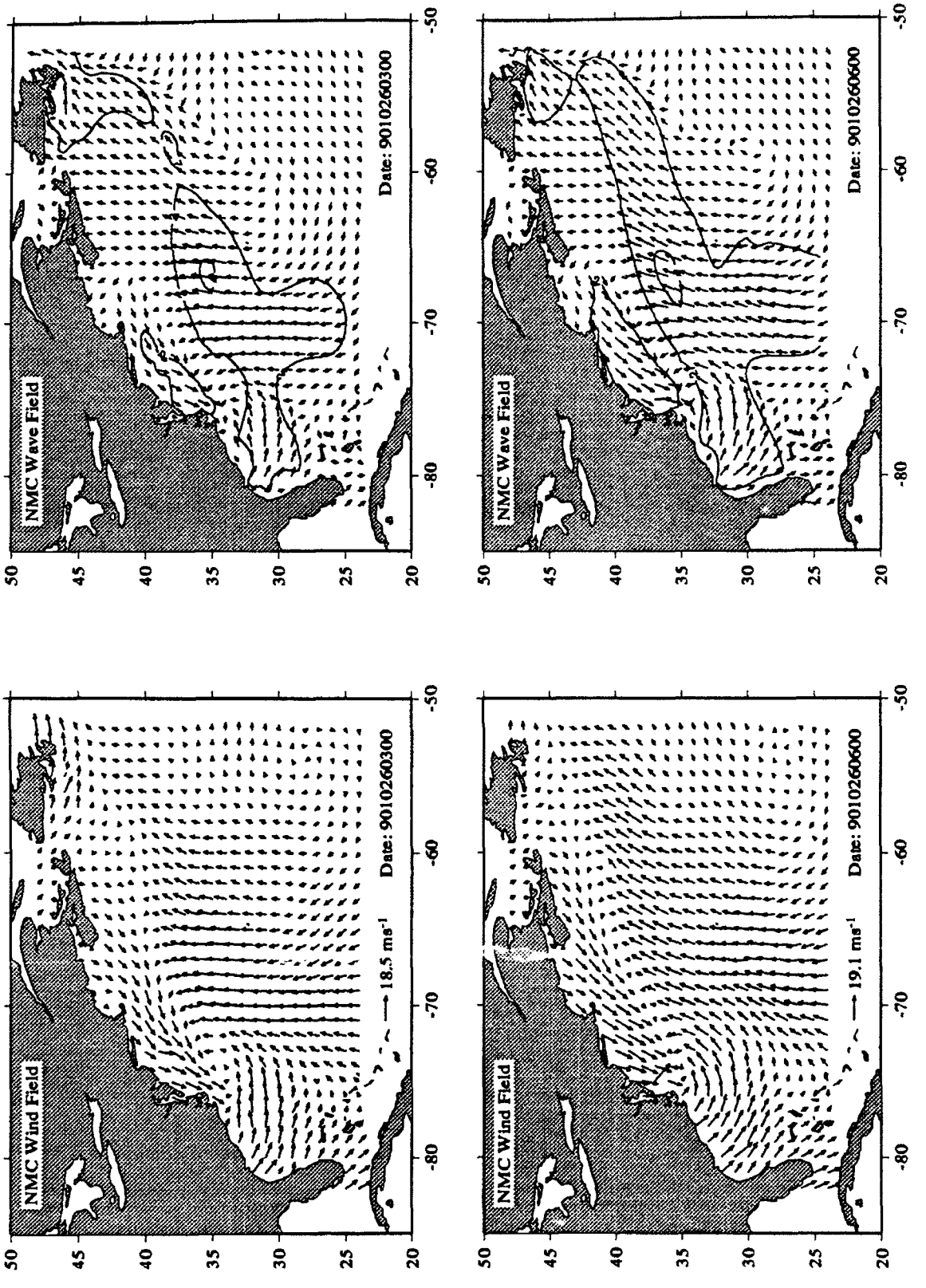
D.4: National Meteorological Center (NMC)

Custer diagrams are presented for the time period from 24 October 1990, 12:00 GMT to 28 October 1990, 12:00 GMT of the wind field and corresponding wave hindcasts. Note that the frequency of maps is every 3 hr from 26-28 October, which covers the major storm period.

NMC Wave Field
Date: 9010241200
NMC Wave Field
Date: 9010250000
NMC Wind Field
14.0 ms-1
Date: 9010241200
NMC Wind Field
16.0 ms-1
Date: 9010250000
50
45
40
35
30
25
20
-50
-60
-70
-80


NMC Wave Field
Date: 9010250600
NMC Wave Field
Date: 9010251200
NMC Wind Field
13.7 ms-1
Date: 9010250600
NMC Wind Field
13.1 ms-1
Date: 9010251200
50
45
40
35
30
25
20
-50
-60
-70
-80


NMC Wave Field
Date: 9010251800
NMC Wave Field
Date: 9010260000
NMC Wind Field
16.7 ms-1
Date: 9010251800
NMC Wind Field
18.5 ms-1
Date: 9010260000
50
45
40
35
30
25
20
-50
-60
-70
-80

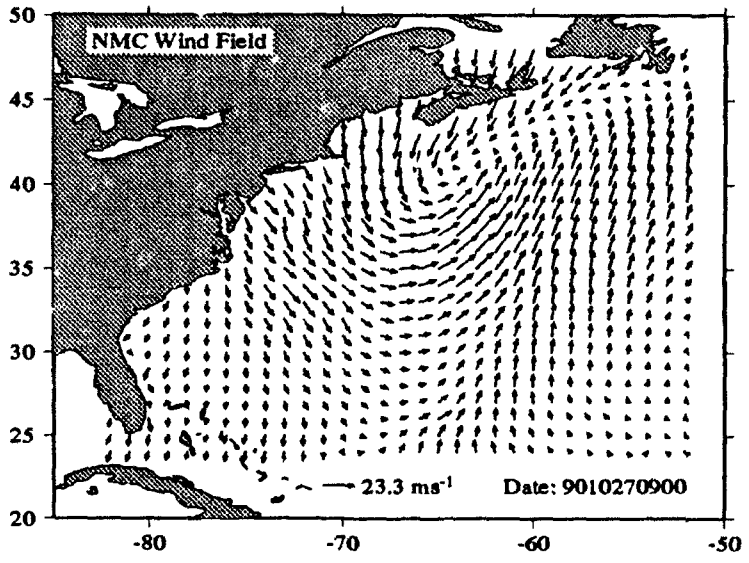

NMC Wave Field
Date: 9010260300
NMC Wave Field
Date: 9010260600
NMC Wind Field
18.5 ms-1
Date: 9010260300
NMC Wind Field
19.1 ms-1
Date: 9010260600
50
45
40
35
30
25
20
-50
-60
-70
-80

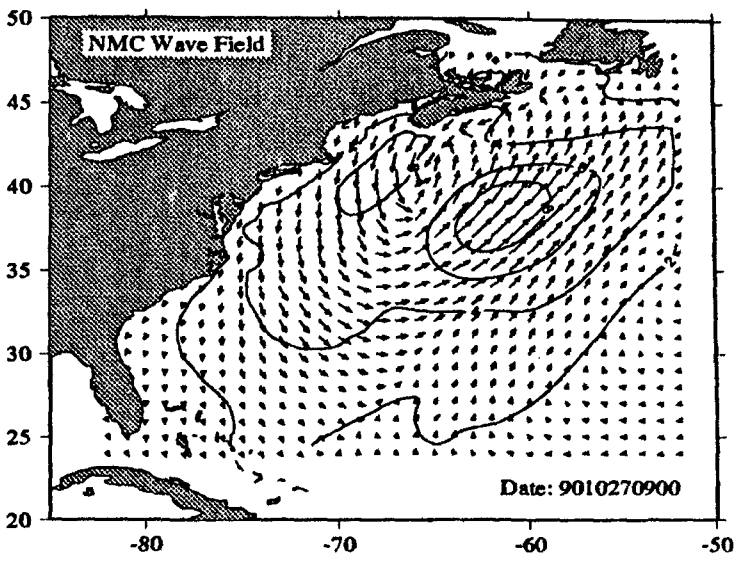
NMC Wind Field
19.1 ms-1
Date: 9010260900
NMC Wave Field
Date: 9010260900
NMC Wind Field
25.3 ms-1
Date: 9010261200
NMC Wave Field
Date: 9010261200
50
45
40
35
30
25
20
-50
-60
-70
-80

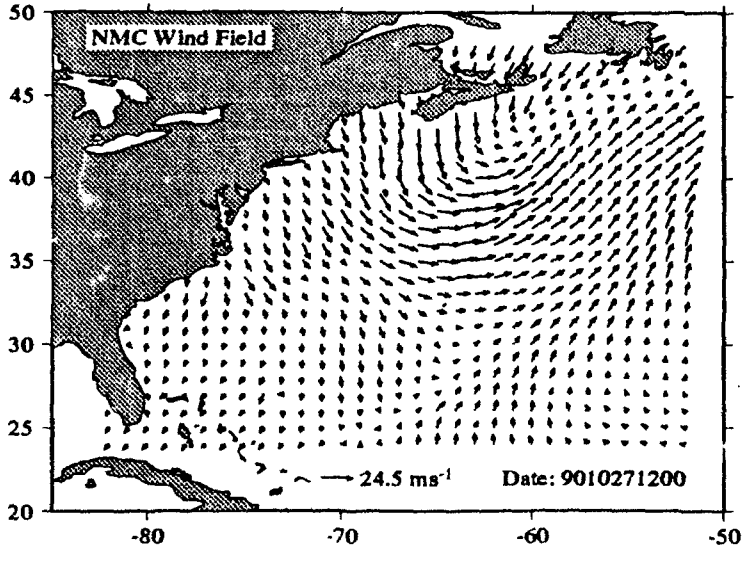
NMC Wave Field
Date: 9010261500
NMC Wave Field
Date: 9010261800
NMC Wind Field
25.3 ms-1
Date: 9010261500
NMC Wind Field
23.8 ms-1
Date: 9010261800
50
45
40
35
30
25
20
-50
-60
-70
-80

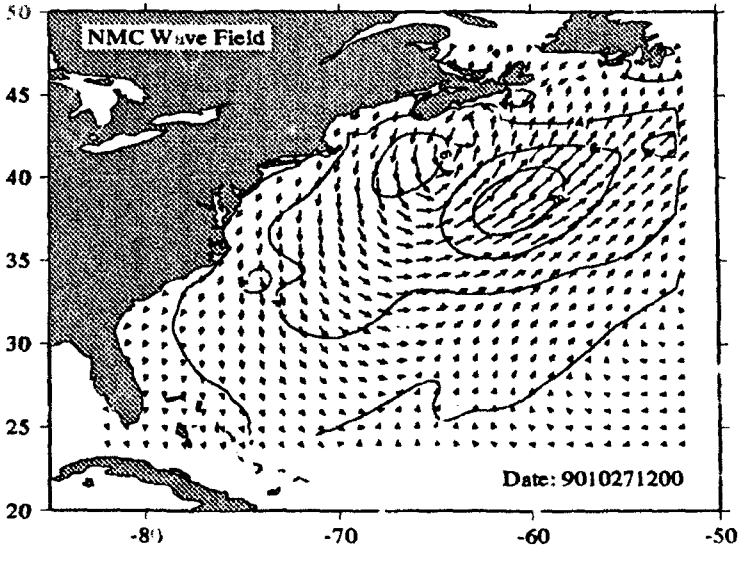
NMC Wave Field
Date: 9010262100
NMC Wave Field
Date: 9010270000
NMC Wind Field
23.8 ms-1
Date: 9010262100
NMC Wind Field
24.2 ms-1
Date: 9010270000
50
45
40
35
30
25
20
-50
-60
-70
-80

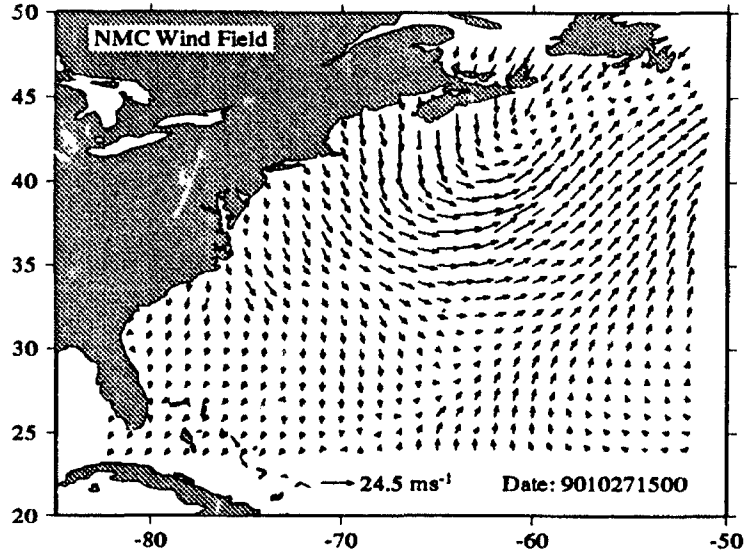
NMC Wave Field
Date: 9010270300
NMC Wave Field
Date: 9010270600
NMC Wind Field
24.1 ms-1
Date: 9010270300
NMC Wind Field
23.3 ms-1
Date: 9010270600
50
45
40
35
30
25
20
-50
-60
-70
-80

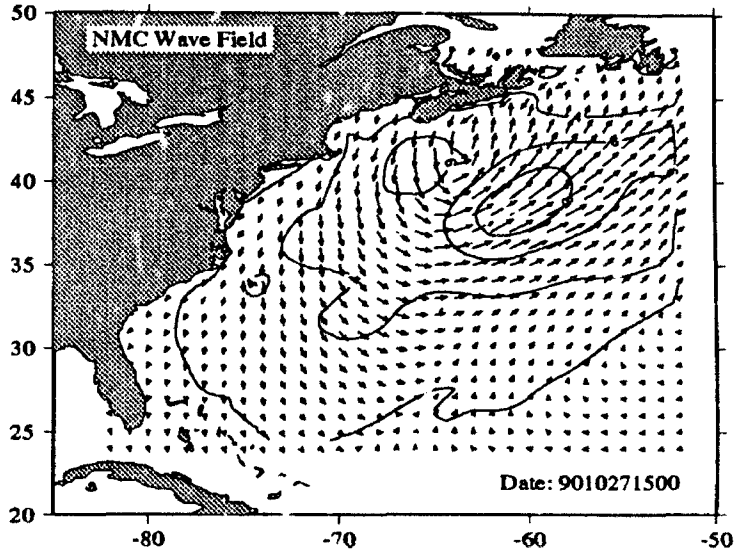

NMC Wind Field
23.3 ms-1
Date: 9010270900
50
45
40
35
30
25
20
-80
-70
-60
-50

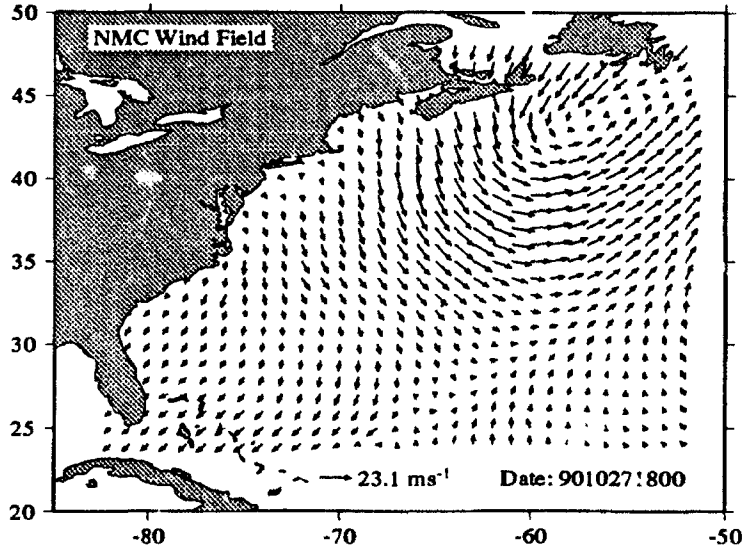

NMC Wave Field
Date: 9010270900
50
45
40
35
30
25
20
-80
-70
-60
-50

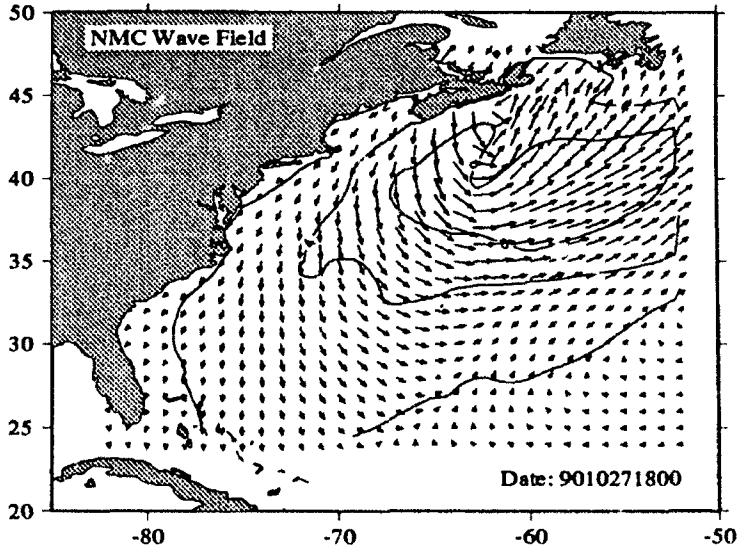

NMC Wind Field
24.5 ms-1
Date: 9010271200
50
45
40
35
30
25
20
-80
-70
-60
-50

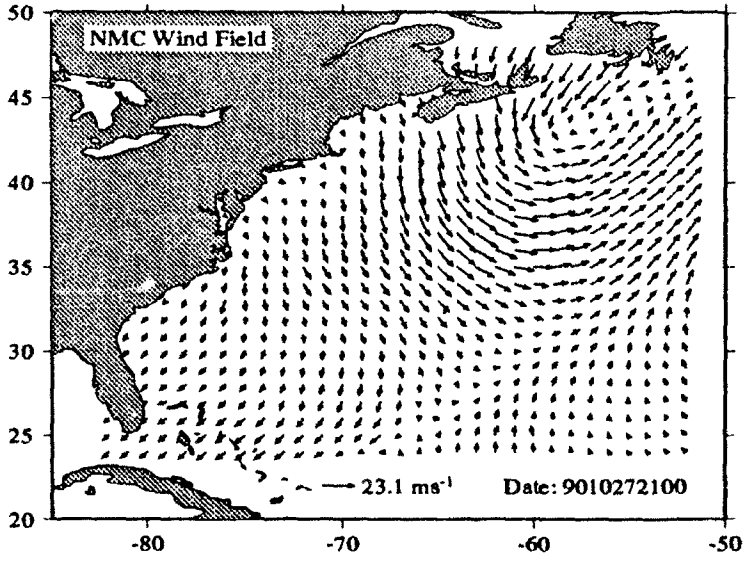

NMC Wave Field
Date: 9010271200
50
45
40
35
30
25
20
-70
-60
-50

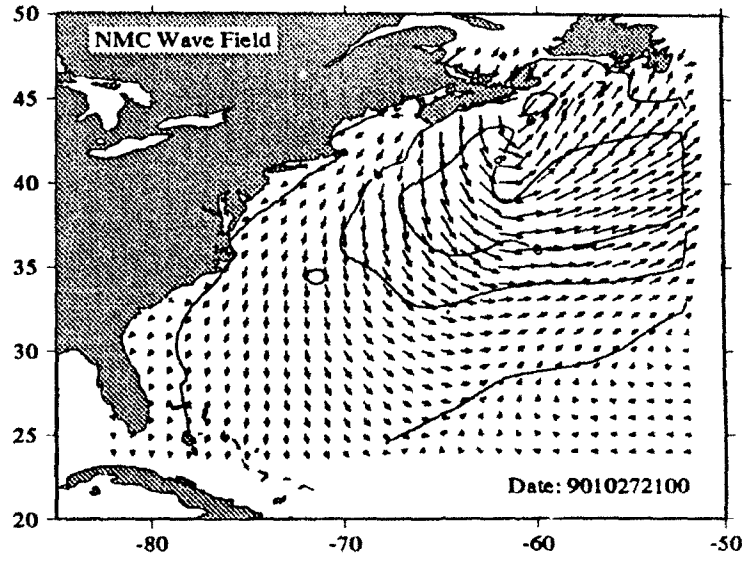

NMC Wind Field
24.5 ms-1
Date: 9010271500
50
45
40
35
30
25
20
-80
-70
-60
-50

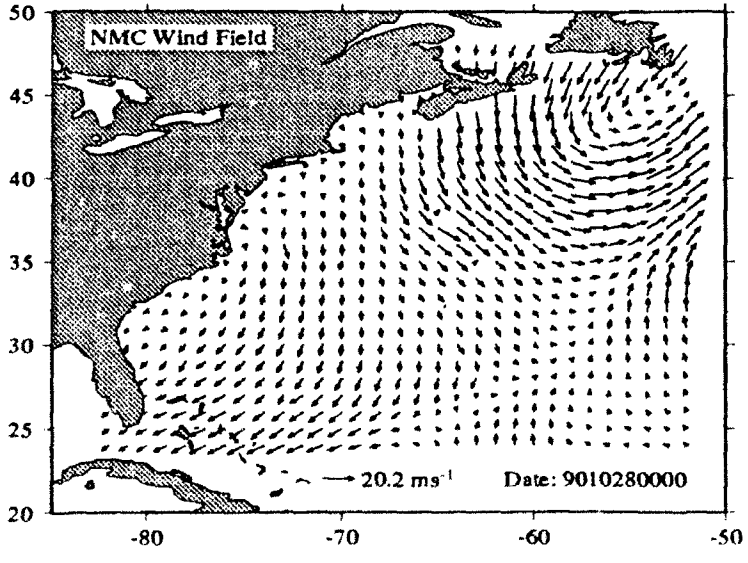

NMC Wave Field
Date: 9010271500
50
45
40
35
30
25
20
-80
-70
-60
-50

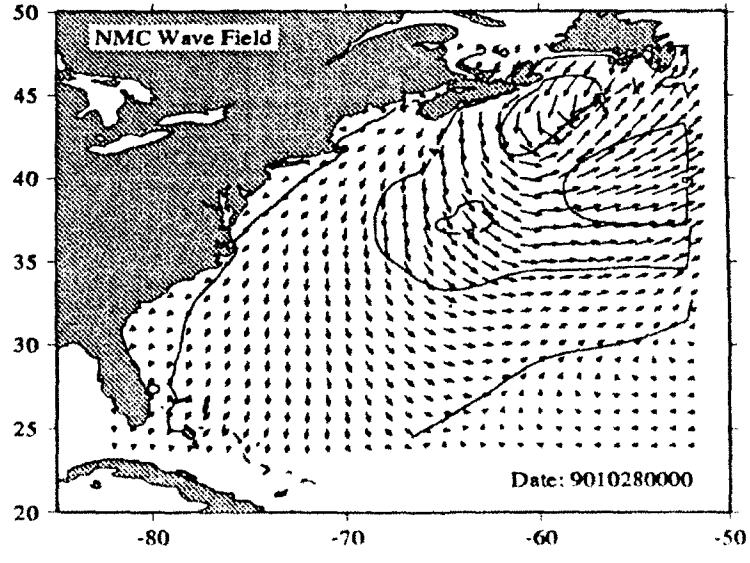

NMC Wind Field
23.1 ms-1
Date: 9010271800
50
45
40
35
30
25
20
-80
-70
-60
-50

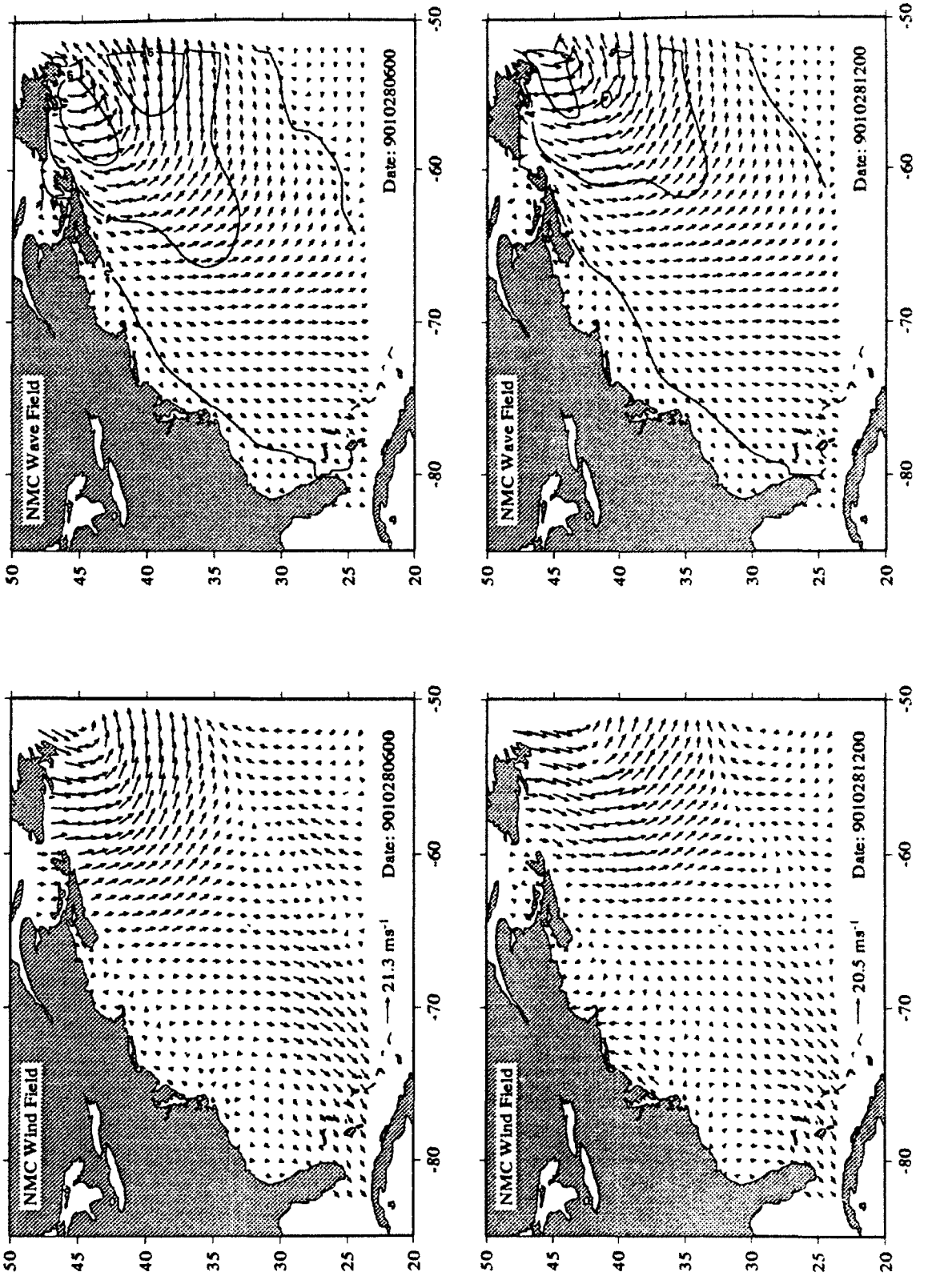

NMC Wave Field
Date: 9010271800
50
45
40
35
30
25
20
-80
-70
-60
-50


NMC Wind Field
23.1 ms-1
Date: 9010272100
50
45
40
35
30
25
20
-80
-70
-60
-50


NMC Wave Field
Date: 9010272100
50
45
40
35
30
25
20
-80
-70
-60
-50


NMC Wind Field
20.2 ms-1
Date: 9010280000
50
45
40
35
30
25
20
-80
-70
-60
-50


NMC Wave Field
Date: 9010280000
50
45
40
35
30
25
20
-80
-70
-60
-50


NMC Wave Field
Date: 9010280600
NMC Wave Field
Date: 9010281200
NMC Wind Field
21.3 ms-1
Date: 9010280600
NMC Wind Field
20.5 ms-1
Date: 9010281200
50
45
40
35
30
25
20
-50
-60
-70
-80

D.5: NASA Goddard Space Flight Facility (GSFC)

Custer diagrams are presented for the time period from 24 October 1990, 12:00 GMT to 28 October 1990, 12:00 GMT of the wind field and corresponding wave hindcasts. Note that the frequency of maps is every 3 hr from 26-28 October, which covers the major storm period.

NASA Wind Field
15.7 ms-1
Date: 9010241200
NASA Wave Field
Date: 9010241200
NASA Wind Field
17.8 ms-1
Date: 9010250000
NASA Wave Field
Date: 9010250000
50
45
40
35
30
25
20
-50
-60
-70
-80

NASA Wave Field
Date: 9010250600
NASA Wave Field
Date: 9010251200
NASA Wind Field
31.7 ms-1
Date: 9010250600
NASA Wind Field
20.0 ms-1
Date: 9010251200

NASA Wave Field
Date: 9010251800
NASA Wave Field
Date: 9010260000
NASA Wind Field
Date: 9010251800
23.4 ms-1
NASA Wind Field
Date: 9010260000
23.7 ms-1
50
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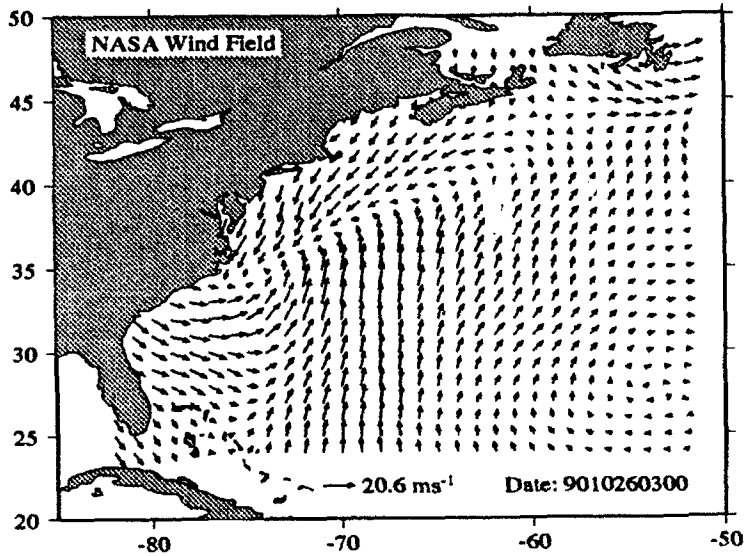
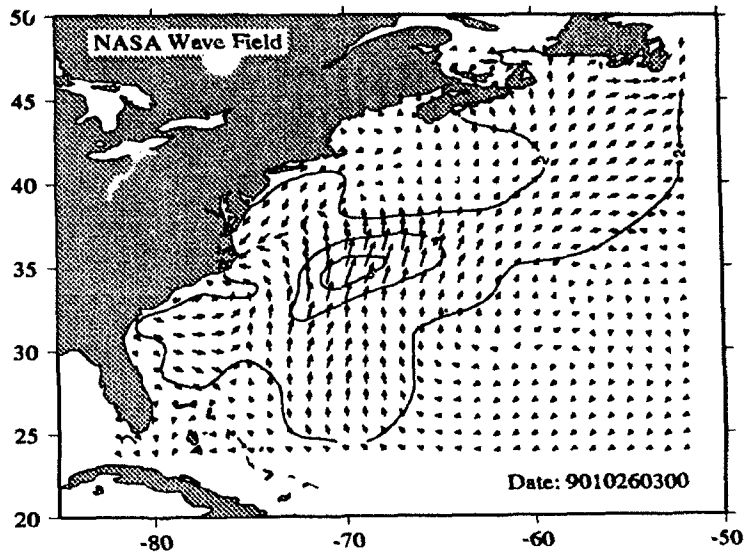
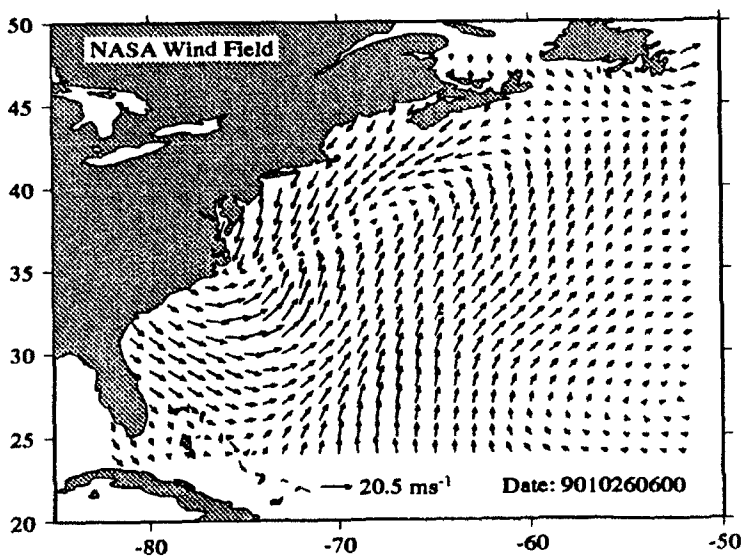
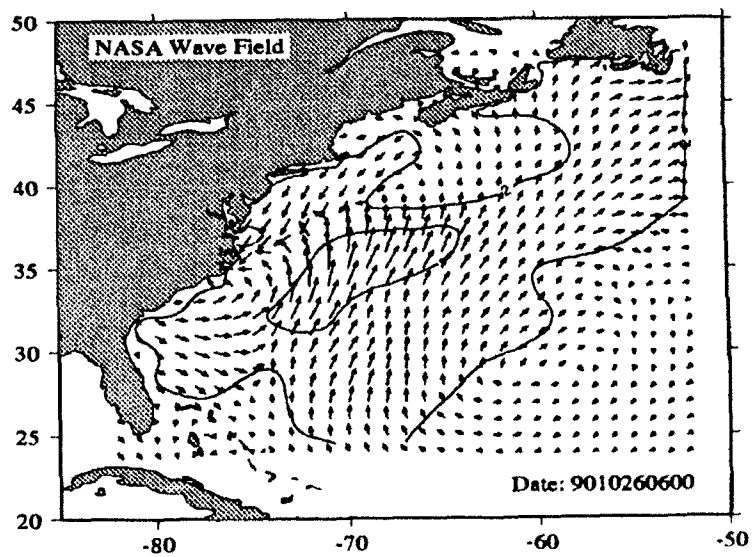
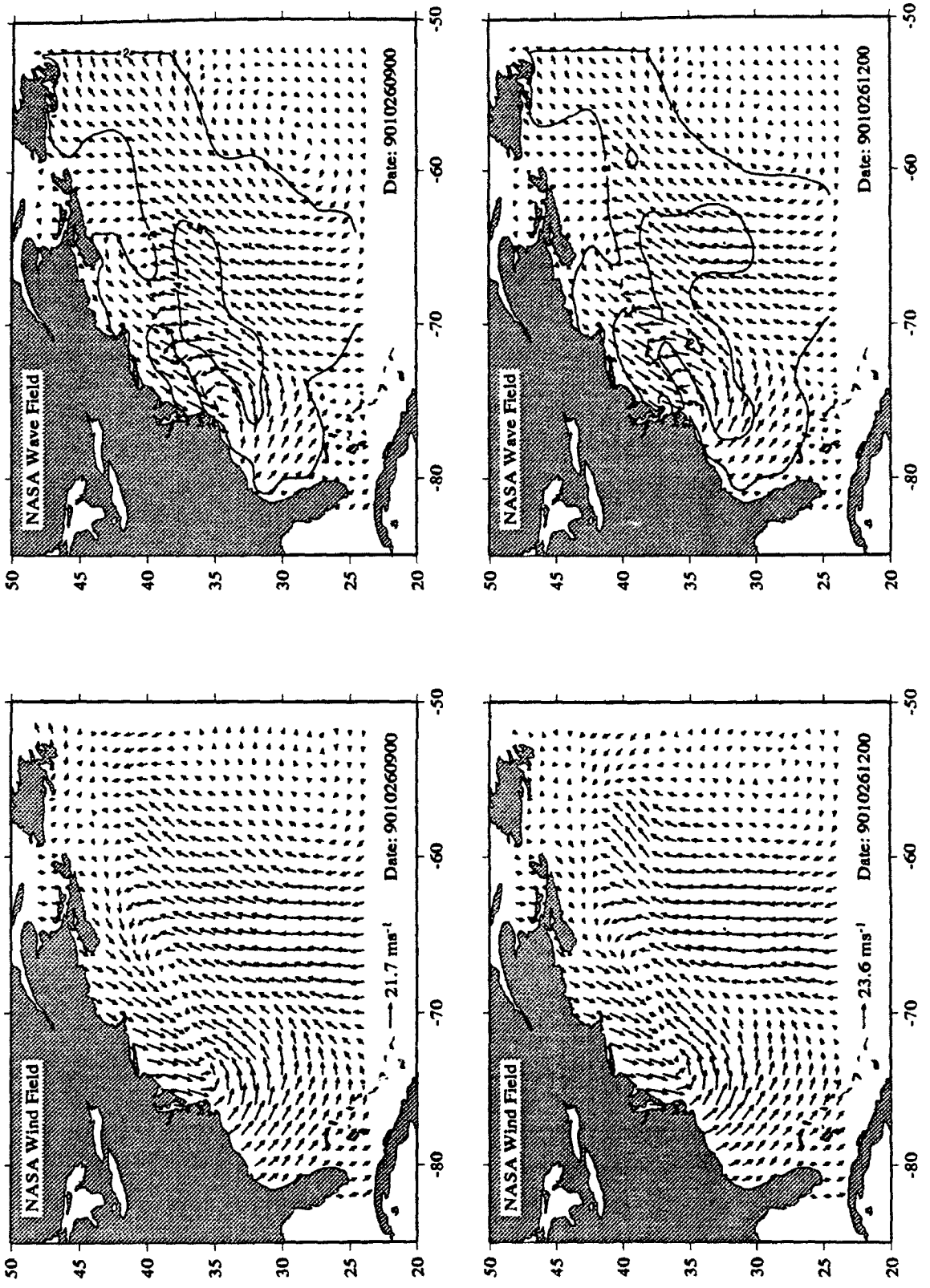
40
35
30
25
20
-50
-60
-70
-80

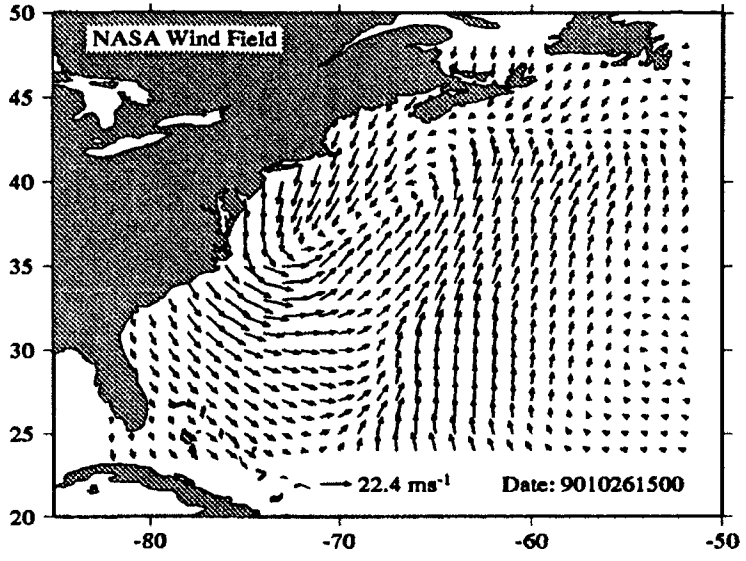

NASA Wind Field
20.6 ms-1
Date: 9010260300
50
45
40
35
30
25
20
-80
-70
-60
-50

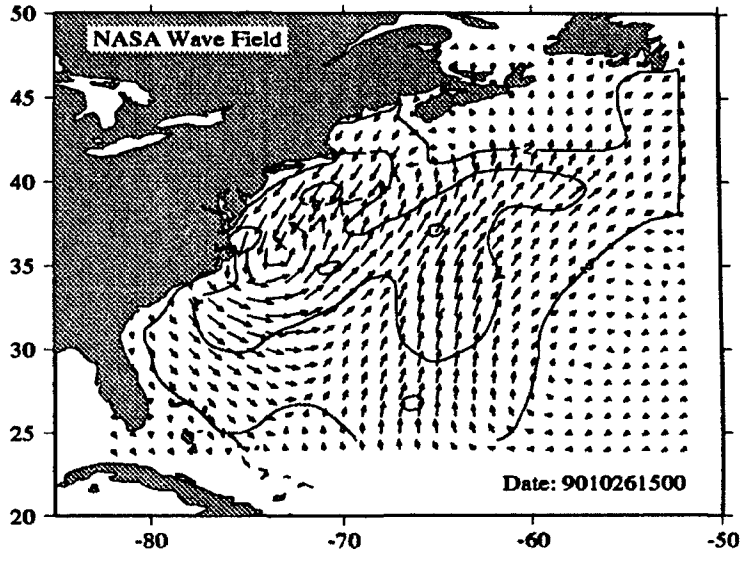

NASA Wave Field
Date: 9010260300
50
45
40
35
30
25
20
-80
-70
-60
-50

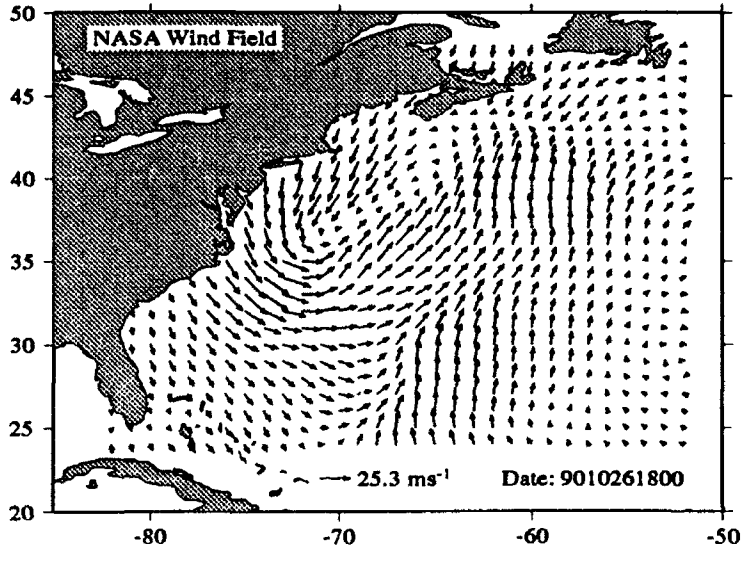

NASA Wind Field
20.5 ms-1
Date: 9010260600
50
45
40
35
30
25
20
-80
-70
-60
-50


NASA Wave Field
Date: 9010260600
50
45
40
35
30
25
20
-80
-70
-60
-50


NASA Wave Field
Date: 9010260900
NASA Wave Field
Date: 9010261200
NASA Wind Field
Date: 9010260900
21.7 ms-1
NASA Wind Field
Date: 9010261200
23.6 ms-1
50
45
40
35
30
25
20
-50
-60
-70
-80


NASA Wind Field
22.4 ms-1
Date: 9010261500
50
45
40
35
30
25
20
-80
-70
-60
-50


NASA Wave Field
Date: 9010261500
50
45
40
35
30
25
20
-80
-70
-60
-50


NASA Wind Field
25.3 ms-1
Date: 9010261800
50
45
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35
30
25
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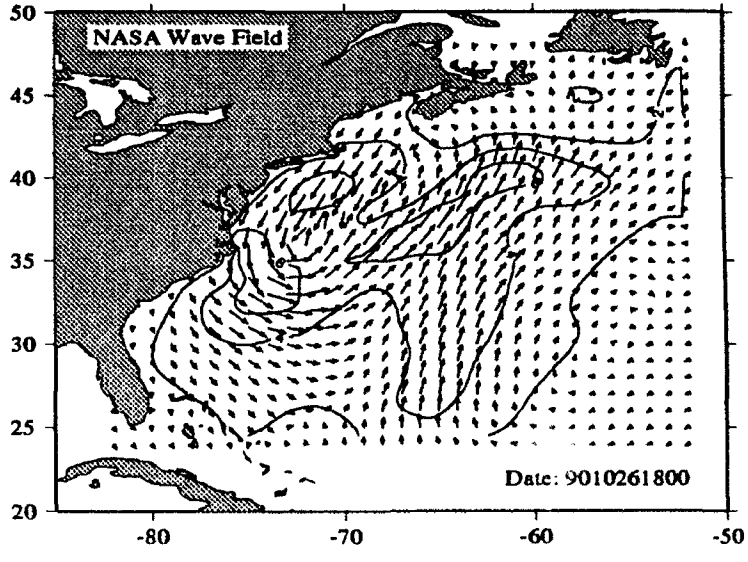
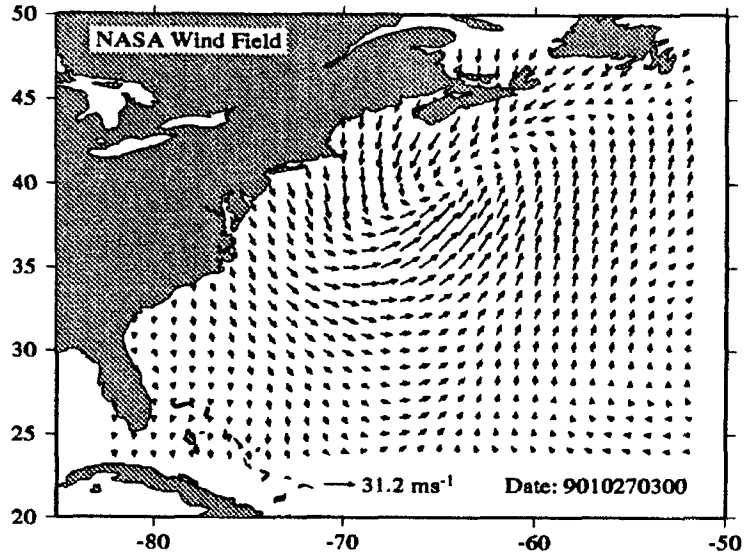
-80
-70
-60
-50


NASA Wave Field
Date: 9010261800
50
45
40
35
30
25
20
-80
-70
-60
-50

NASA Wave Field
Date: 9010262100
NASA Wave Field
Date: 9010270000
NASA Wind Field
29.7 ms-1
Date: 9010262100
NASA Wind Field
35.2 ms-1
Date: 9010270000
50
45
40
35
30
25
20
-50
-60
-70
-80


NASA Wind Field
31.2 ms-1
Date: 9010270300
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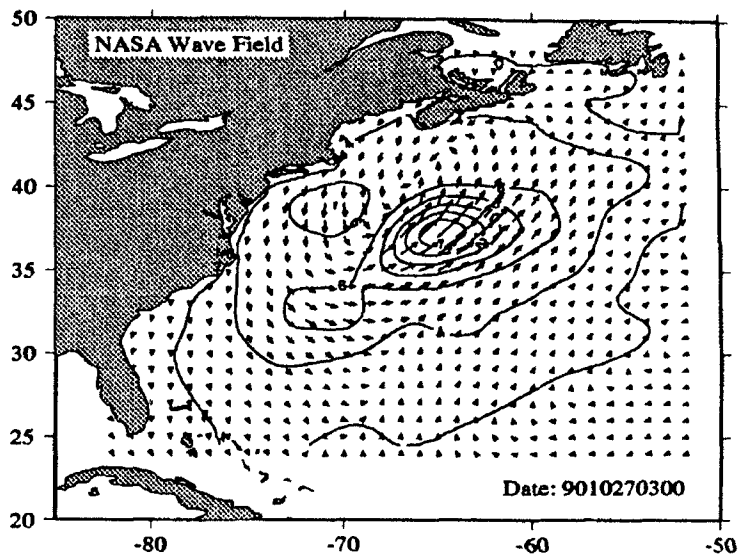
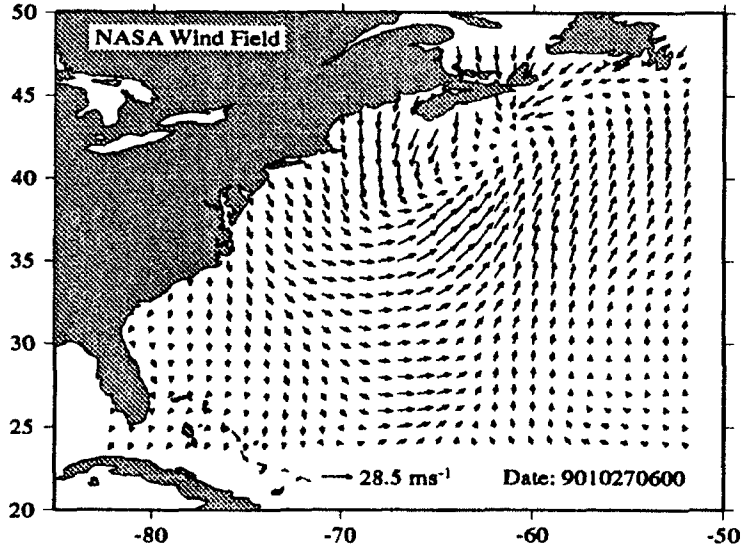
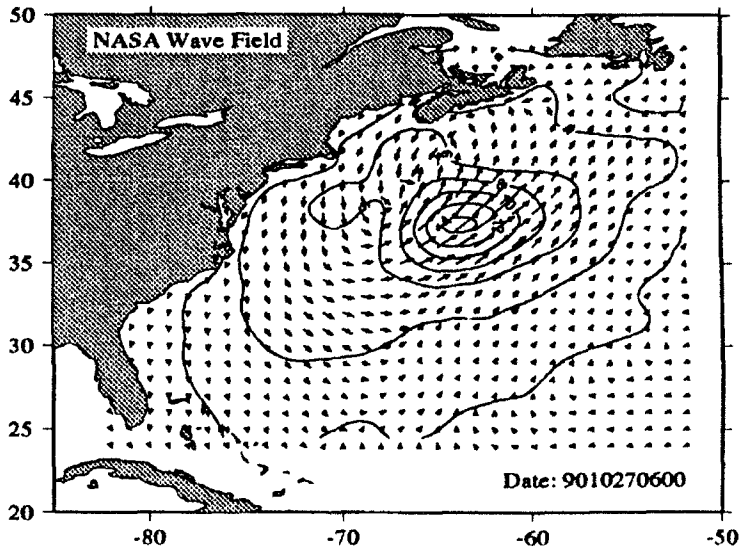
45
40
35
30
25
20
-80
-70
-60
-50


NASA Wave Field
Date: 9010270300
50
45
40
35
30
25
20
-80
-70
-60
-50

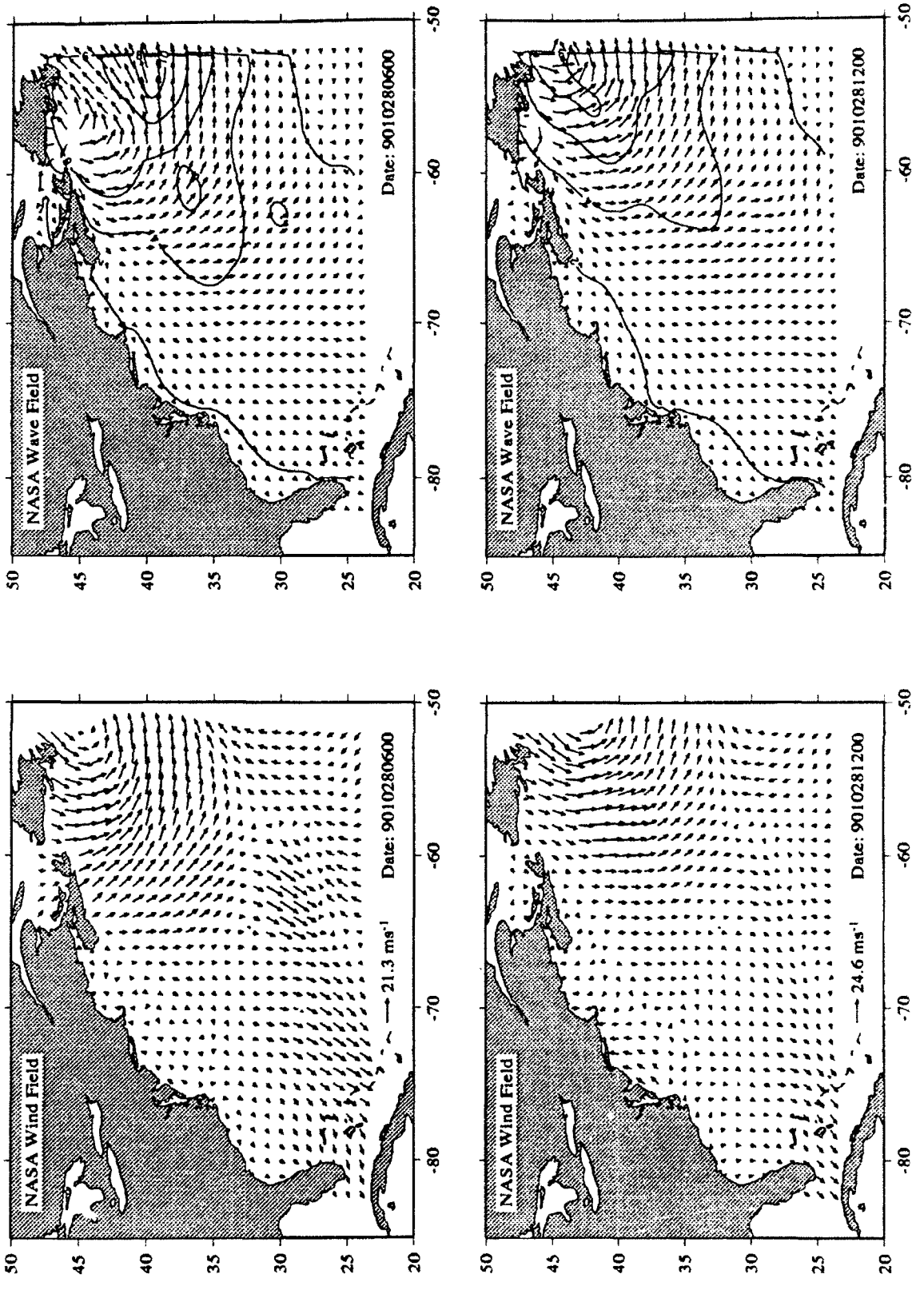

NASA Wind Field
28.5 ms-1
Date: 9010270600
50
45
40
35
30
25
20
-80
-70
-60
-50


NASA Wave Field
Date: 9010270600
50
45
40
35
30
25
20
-80
-70
-60
-50

NASA Wave Field
Date: 9010270900
NASA Wave Field
Date: 9010271200
NASA Wind Field
Date: 9010270900
26.9 ms-1
NASA Wind Field
Date: 9010271200
29.2 ms-1
50
45
40
35
30
25
20
-50
-60
-70
-80

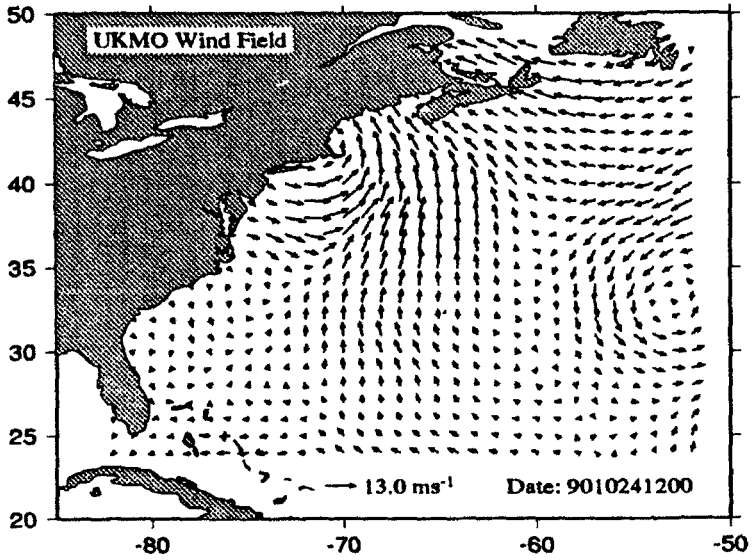
NASA Wave Field
Date: 9010271500
NASA Wave Field
Date: 9010271800
NASA Wind Field
23.6 ms-1
Date: 9010271500
NASA Wind Field
26.9 ms-1
Date: 9010271800

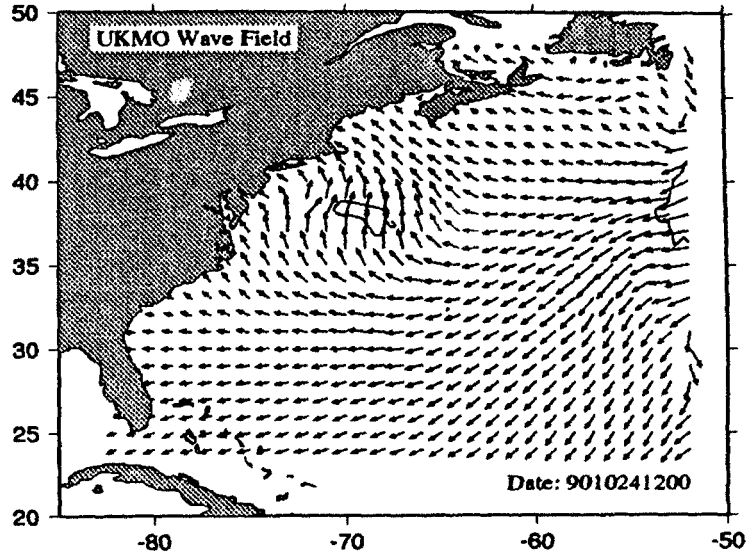
NASA Wave Field
Date: 9010272100
NASA Wave Field
Date: 9010280000
NASA Wind Field
26.2 ms-1
Date: 9010272100
NASA Wind Field
26.3 ms-1
Date: 9010280000
50
45
40
35
30
25
20
-50
-60
-70
-80

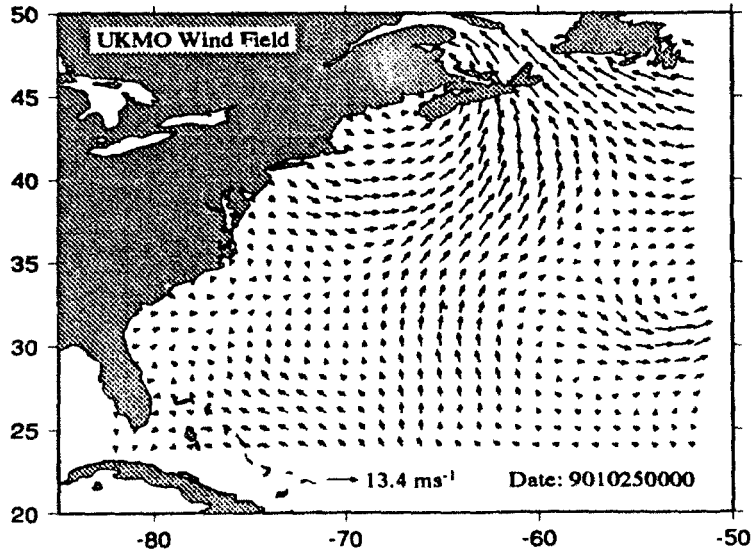

NASA Wave Field
Date: 9010280600
NASA Wave Field
Date: 9010281200
NASA Wind Field
Date: 9010280600
21.3 ms-1
NASA Wind Field
Date: 9010281200
24.6 ms-1
50
45
40
35
30
25
20
-50
-60
-70
-80

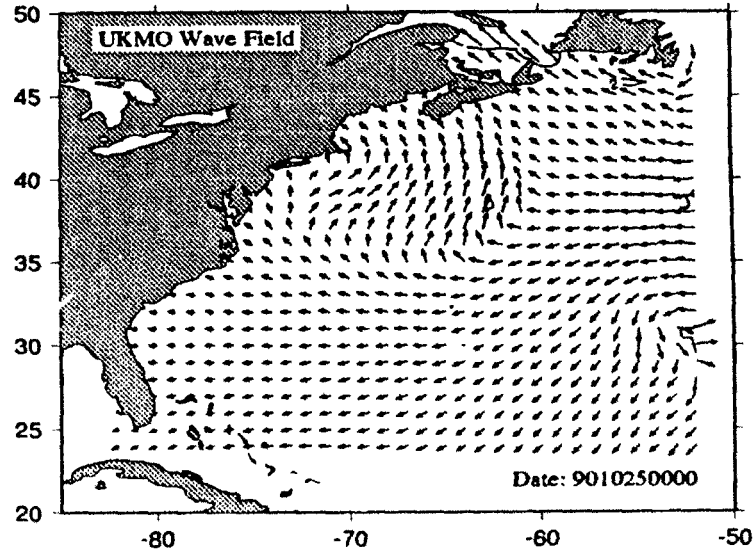
D.6: United Kingdom Meteorological Office (UKMO)

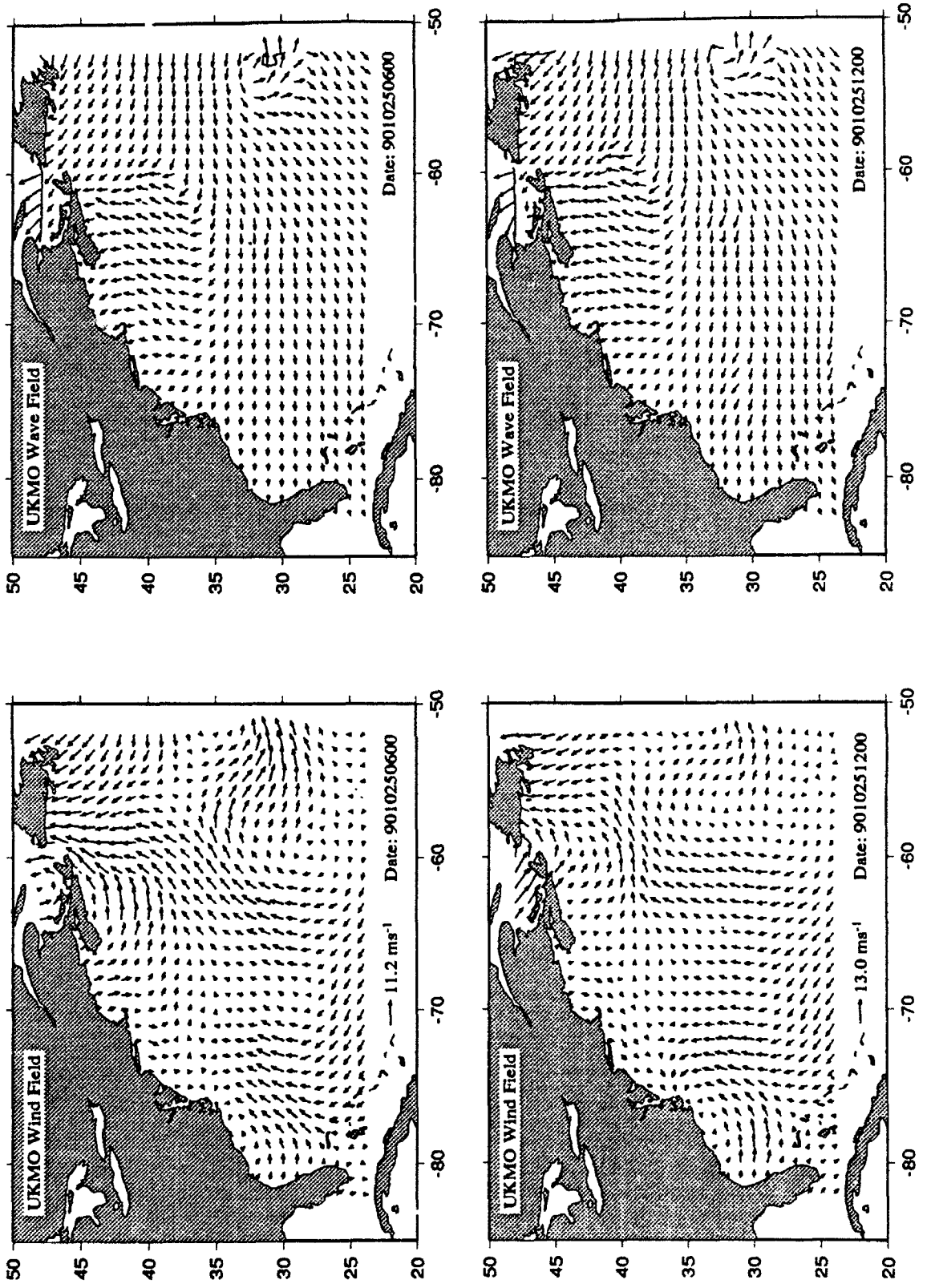
Custer diagrams are presented for the time period from 24 October 1990, 12:00 GMT to 28 October 1990, 12:00 GMT of the wind field and corresponding wave hindcasts. Note that the frequency of maps is every 3 hr from 26-28 October, which covers the major storm period.


UKMO Wind Field
13.0 ms-1
Date: 9010241200
50
45
40
35
30
25
20
-80
-70
-60
-50

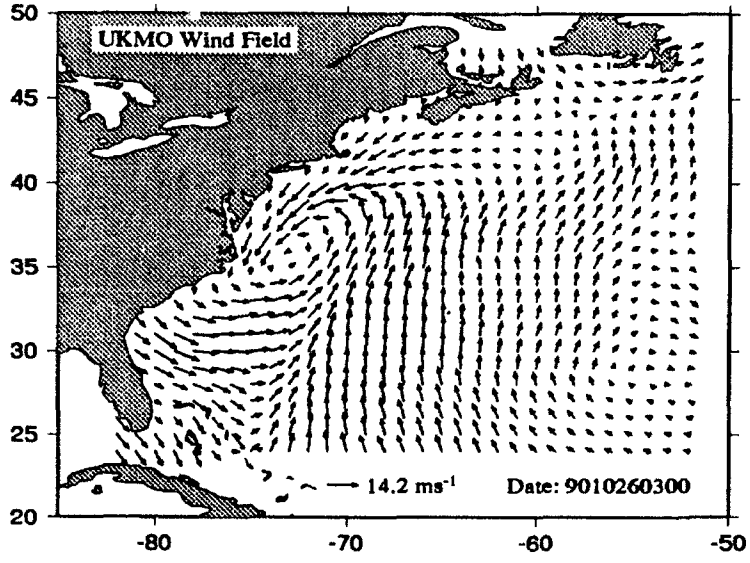

UKMO Wave Field
Date: 9010241200
50
45
40
35
30
25
20
-80
-70
-60
-50

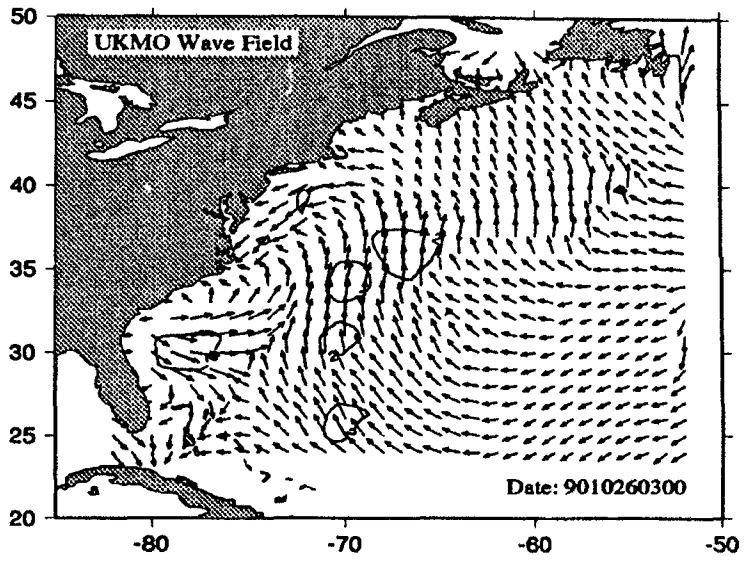

UKMO Wind Field
13.4 ms-1
Date: 9010250000
50
45
40
35
30
25
20
-80
-70
-60
-50

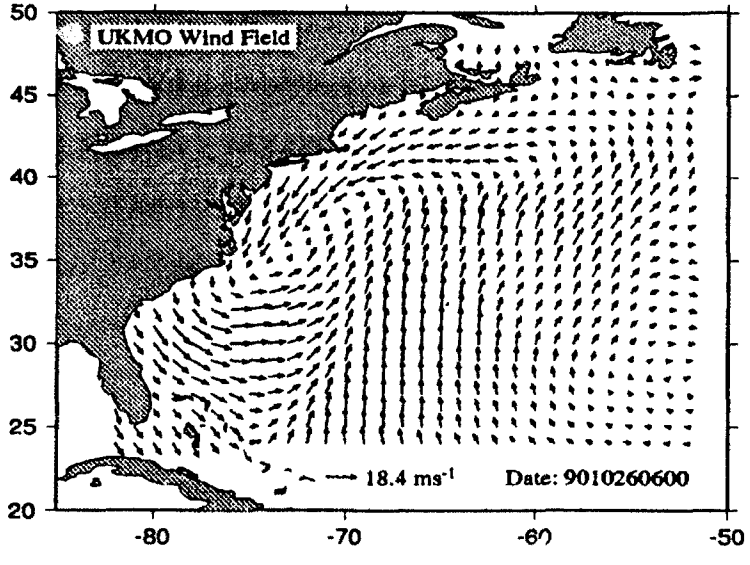

UKMO Wave Field
Date: 9010250000
50
45
40
35
30
25
20
-80
-70
-60
-50

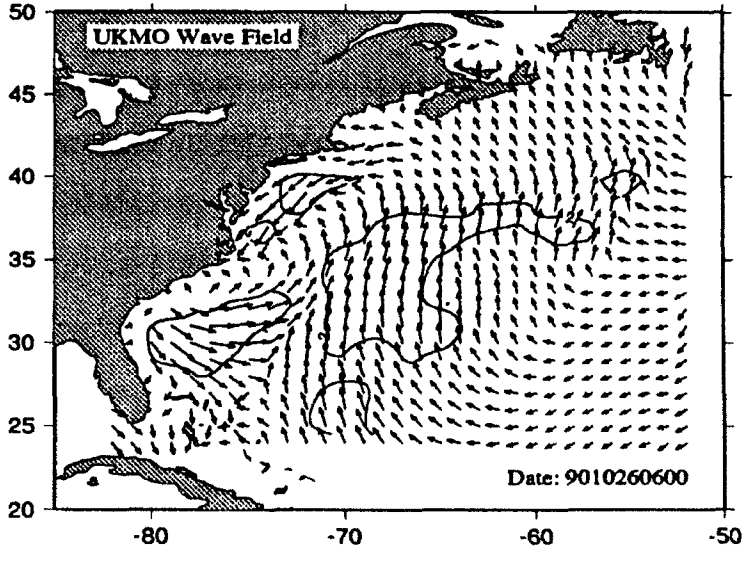

UKMO Wave Field
Date: 9010250600
UKMO Wave Field
Date: 9010251200
UKMO Wind Field
11.2 ms-1
Date: 9010250600
UKMO Wind Field
13.0 ms-1
Date: 9010251200
50
45
40
35
30
25
20
-50
-60
-70
-80

UKMO Wave Field
Date: 9010251800
UKMO Wave Field
Date: 9010260000
UKMO Wind Field
11.6 ms-1
Date: 9010251800
UKMO Wind Field
14.8 ms-1
Date: 9010260000
50
45
40
35
30
25
20
-50
-60
-70
-80


UKMO Wind Field
14.2 ms-1
Date: 9010260300
50
45
40
35
30
25
20
-80
-70
-60
-50


UKMO Wave Field
Date: 9010260300
50
45
40
35
30
25
20
-80
-70
-60
-50

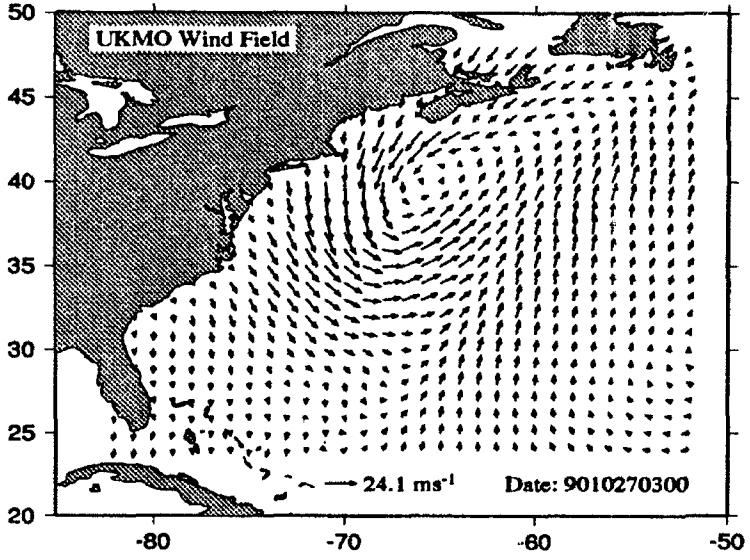

UKMO Wind Field
18.4 ms-1
Date: 9010260600
50
45
40
35
30
25
20
-80
-70
-60
-50


UKMO Wave Field
Date: 9010260600
50
45
40
35
30
25
20
-80
-70
-60
-50

UKMO Wave Field
Date: 9010260900
UKMO Wave Field
Date: 9010261200
UKMO Wind Field
18.4 ms-1
Date: 9010260900
UKMO Wind Field
21.1 ms-1
Date: 9010261200
50
45
40
35
30
25
20
-50
-60
-70
-80

UKMO Wave Field
Date: 9010261500
UKMO Wave Field
Date: 9010261800
UKMO Wind Field
21.3 ms-1
Date: 9010261500
UKMO Wind Field
23.6 ms-1
Date: 9010261800
50
45
40
35
30
25
20
-50
-60
-70
-80

UKMO Wave Field
Date: 9010262100
UKMO Wave Field
Date: 9010270000
UKMO Wind Field
23.4 ms-1
Date: 9010262100
UKMO Wind Field
24.9 ms-1
Date: 9010270000
50
45
40
35
30
25
20
-50
-60
-70
-80


UKMO Wind Field
24.1 ms-1
Date: 9010270300
50
45
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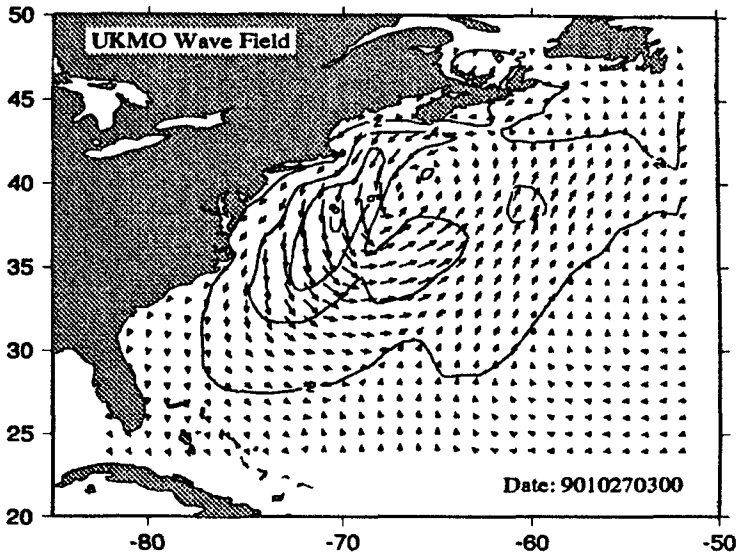
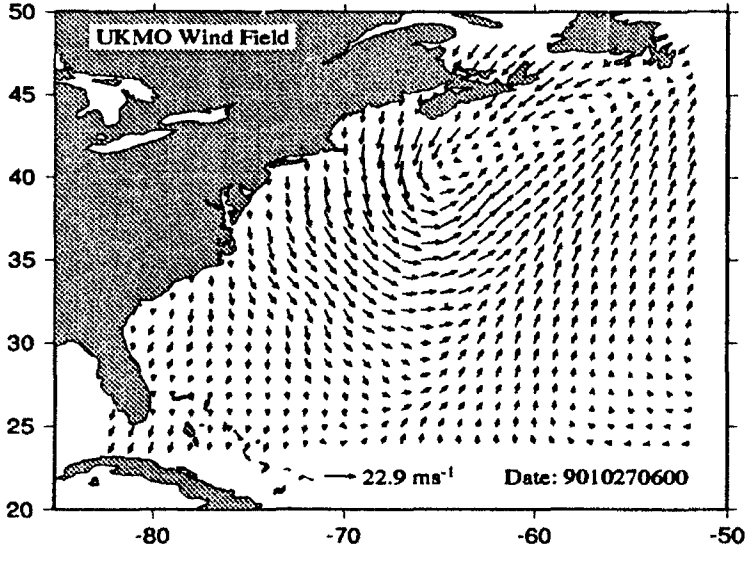
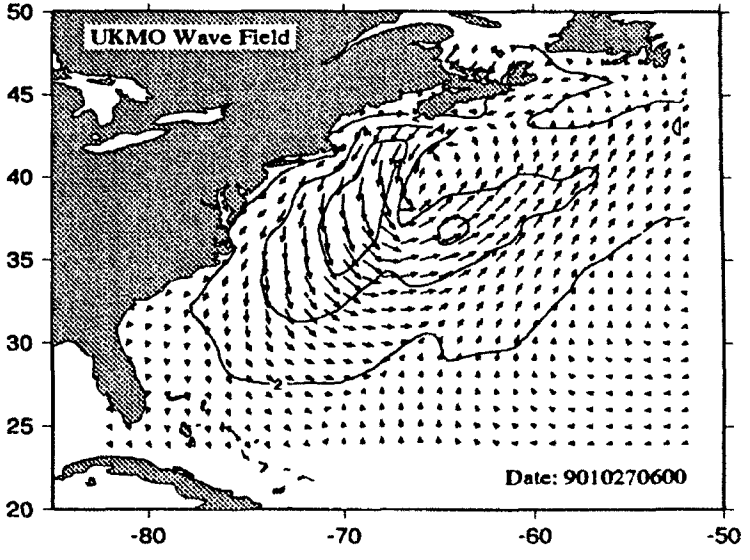
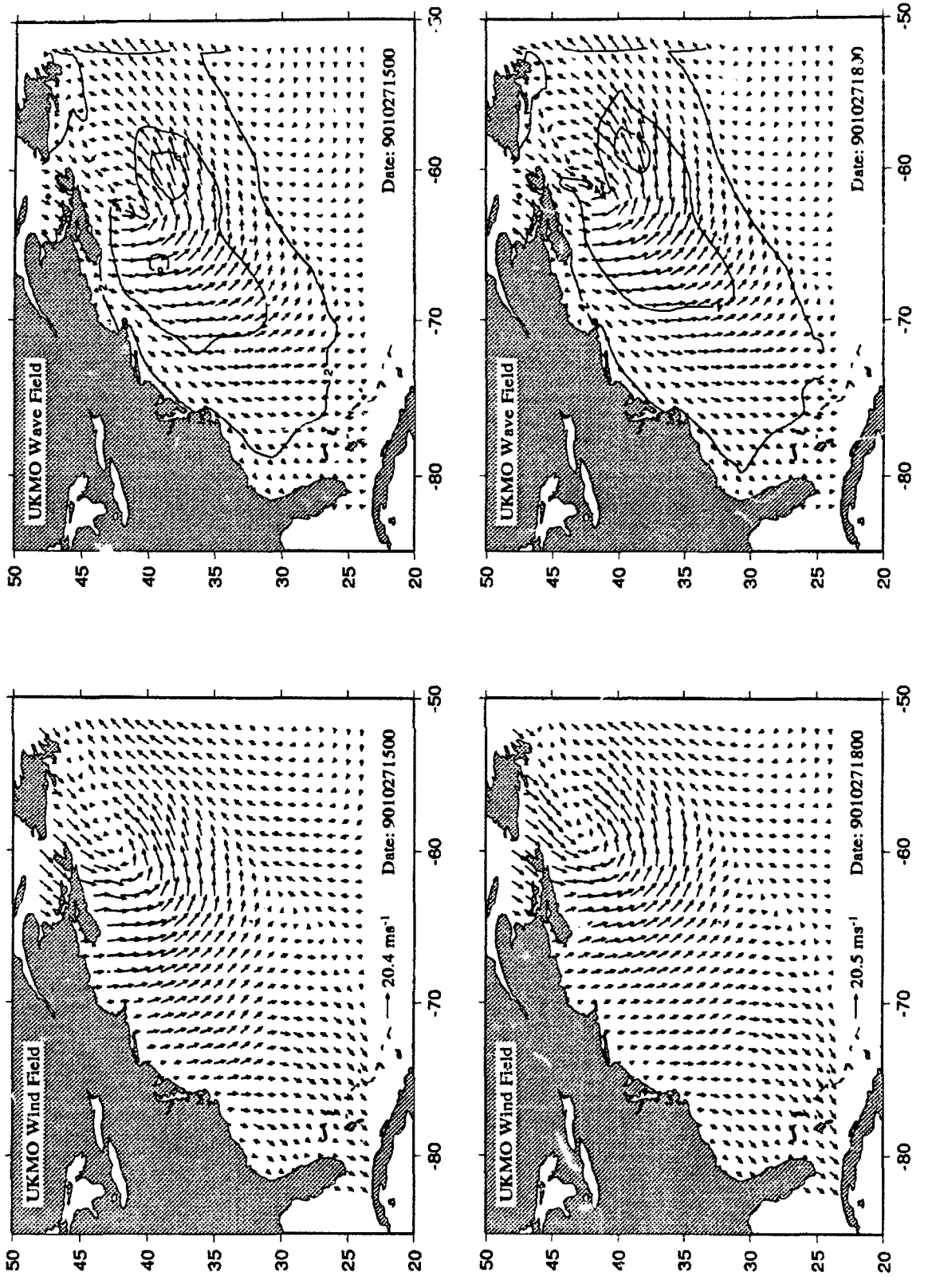
35
30
25
20
-80
-70
-60
-50

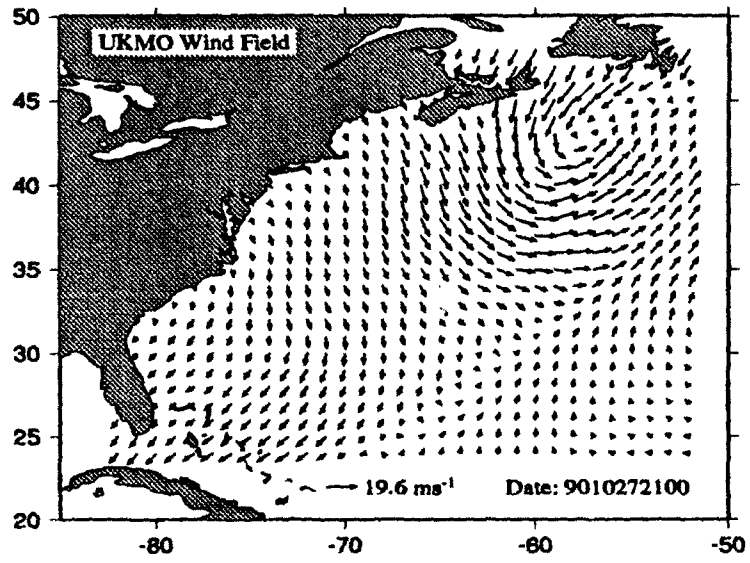

UKMO Wave Field
Date: 9010270300
50
45
40
35
30
25
20
-80
-70
-60
-50

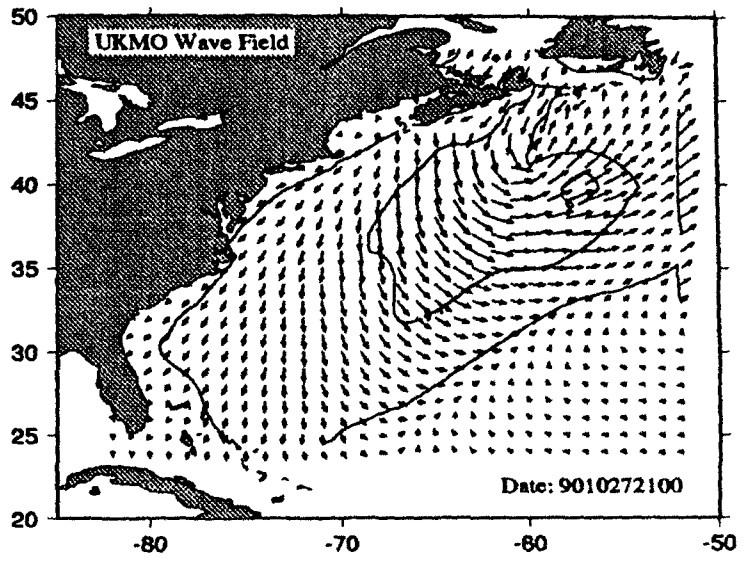

UKMO Wind Field
22.9 ms-1
Date: 9010270600
50
45
40
35
30
25
20
-80
-70
-60
-50

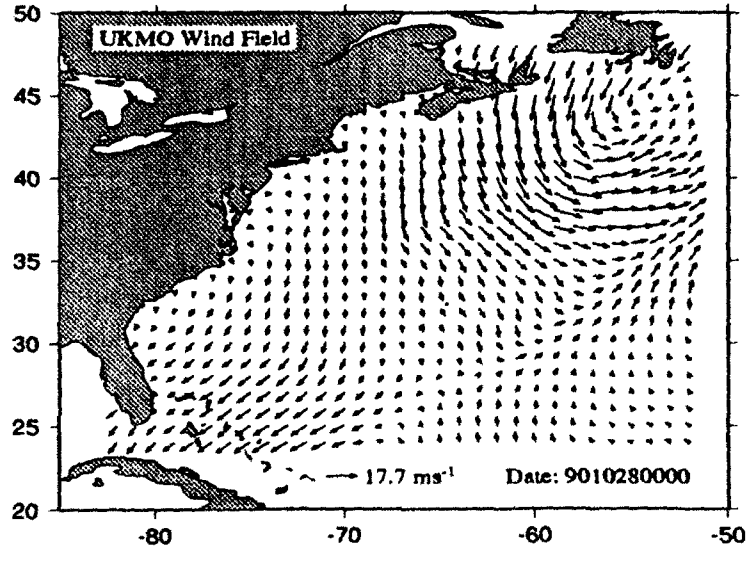

UKMO Wave Field
Date: 9010270600
50
45
40
35
30
25
20
-80
-70
-60
-50

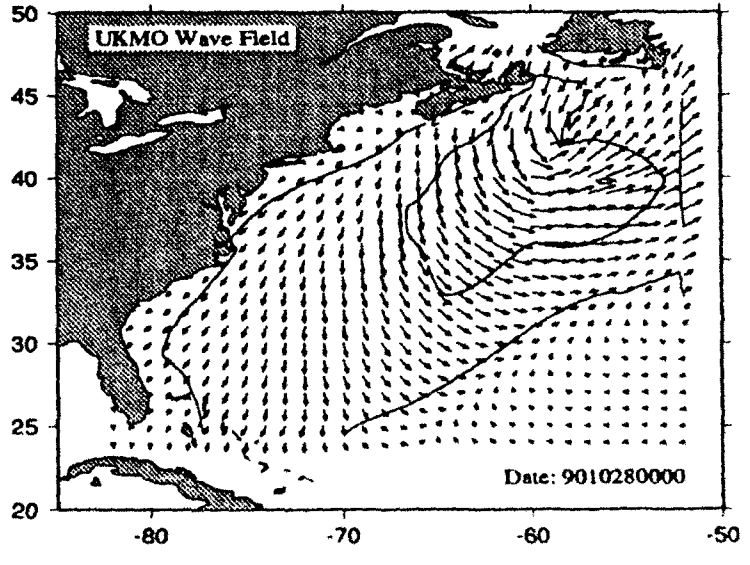
UKMO Wind Field
Date: 9010270900
20.9 ms-1
UKMO Wave Field
Date: 9010270900
UKMO Wind Field
Date: 9010271200
22.7 ms-1
UKMO Wave Field
Date: 9010271200
50
45
40
35
30
25
20
-50
-60
-70
-80


UKMO Wave Field
Date: 9010271500
UKMO Wave Field
Date: 9010271800
UKMO Wind Field
Date: 9010271500
20.4 ms-1
UKMO Wind Field
Date: 9010271800
20.5 ms-1
50
45
40
35
30
25
20
-50
-60
-70
-80


UKMO Wind Field
19.6 ms-1
Date: 9010272100
50
45
40
35
30
25
20
-80
-70
-60
-50


UKMO Wave Field
Date: 9010272100
50
45
40
35
30
25
20
-80
-70
-60
-50

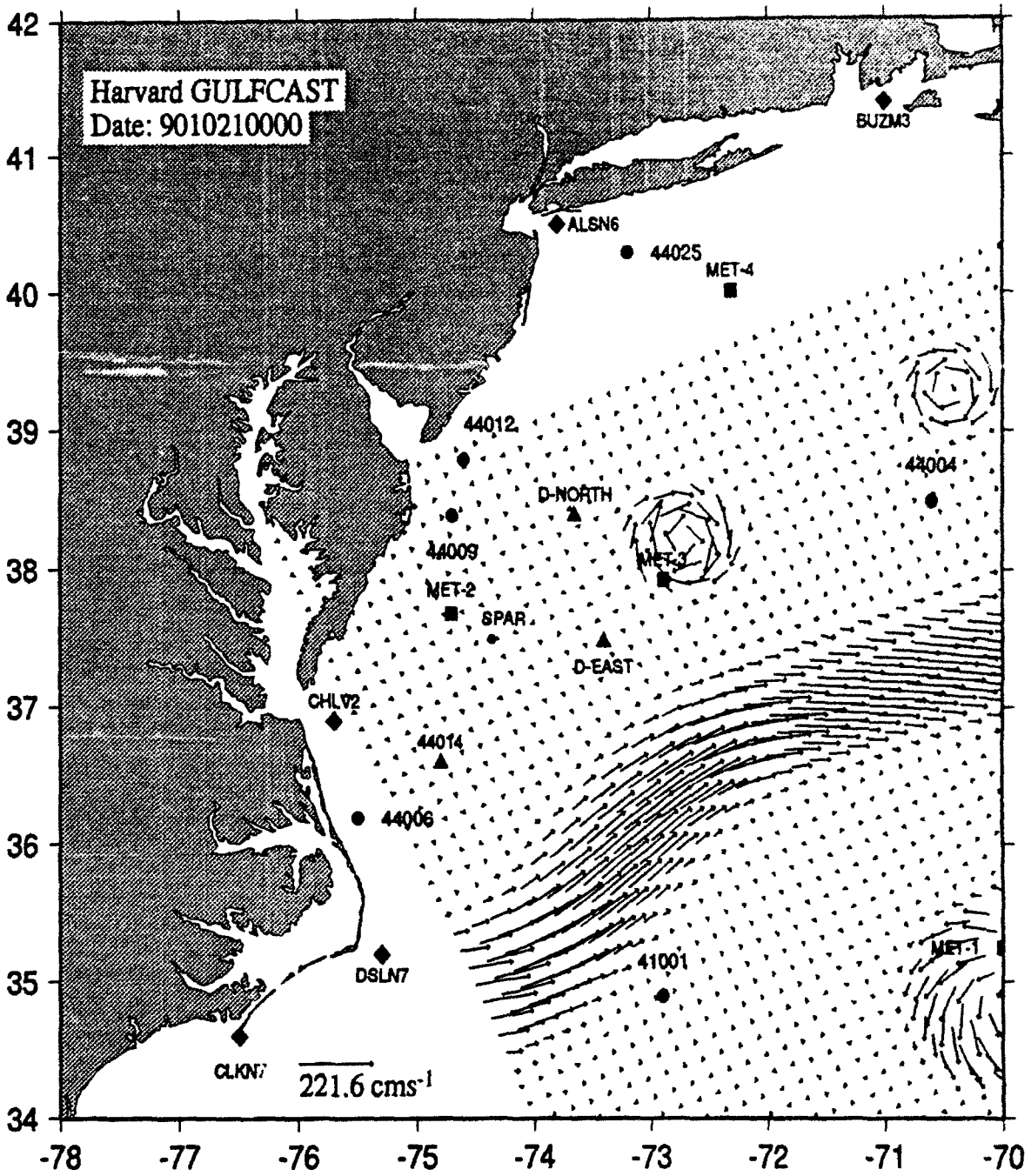

UKMO Wind Field
17.7 ms-1
Date: 9010280000
50
45
40
35
30
25
20
-80
-70
-60
-50

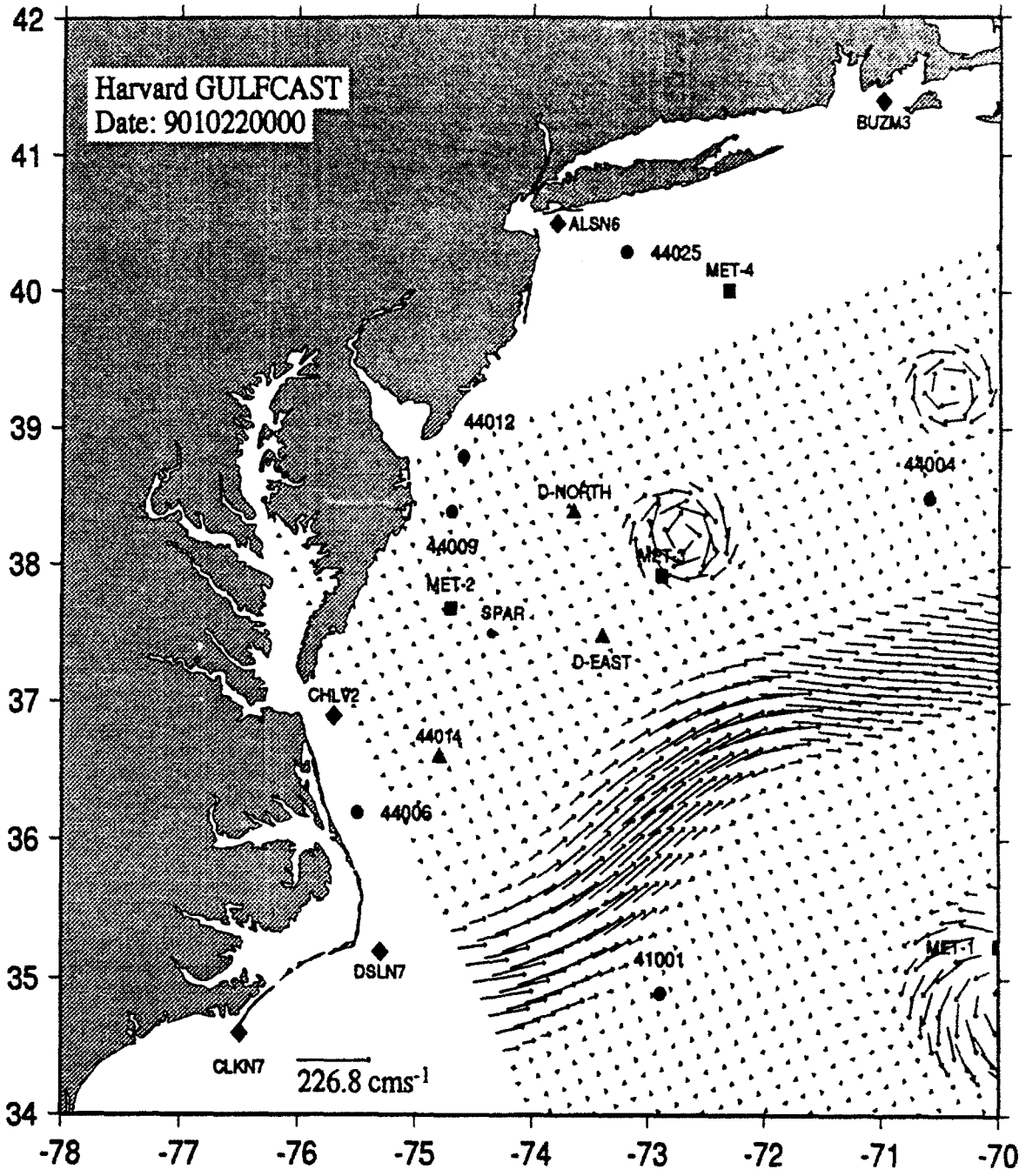

UKMO Wave Field
Date: 9010280000
50
45
40
35
30
25
20
-80
-70
-60
-50

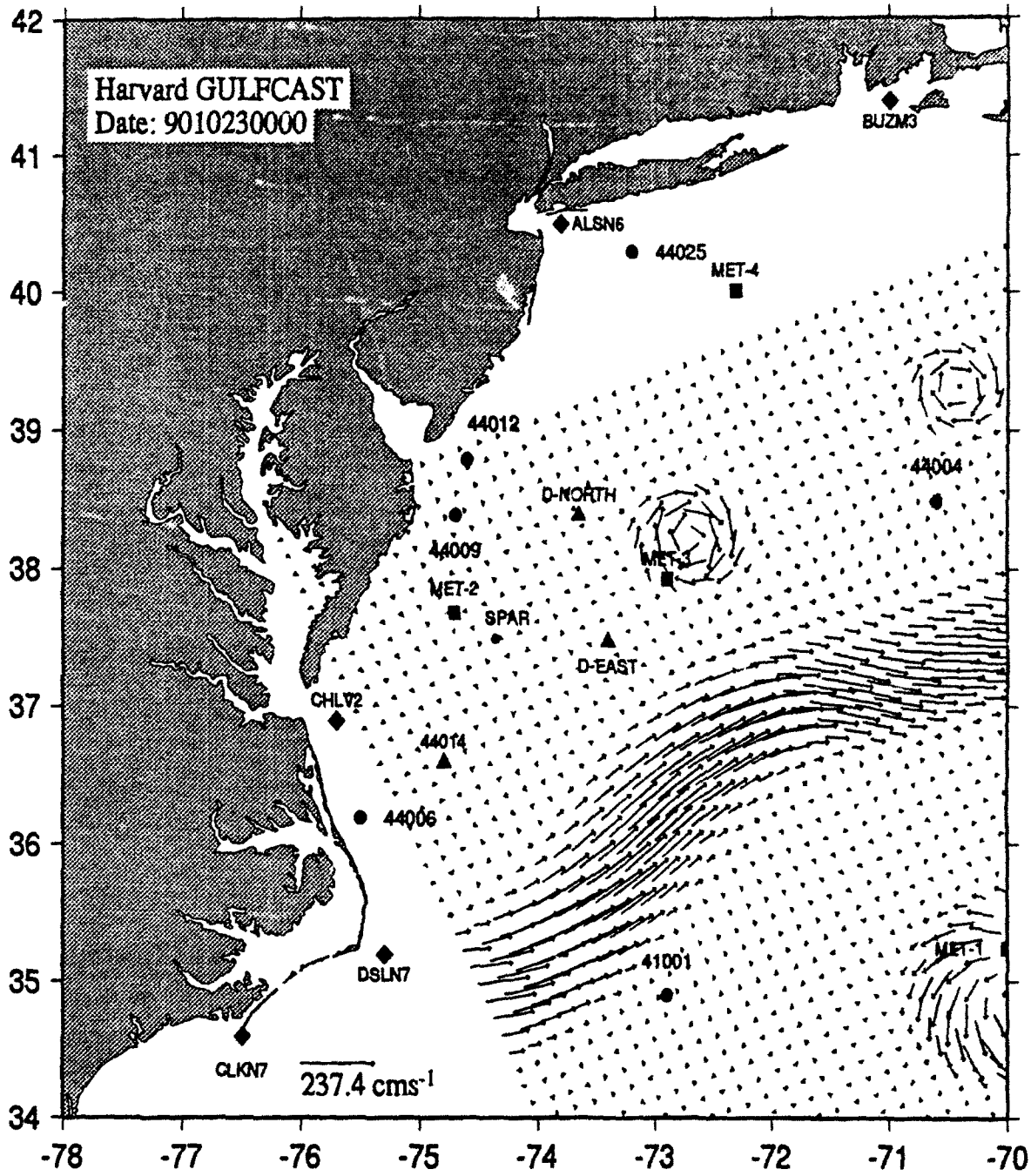
UKMO Wave Field
Date: 9010280600
UKMO Wave Field
Date: 9010281200
UKMO Wind Field
Date: 9010280600
19.0 ms-1
UKMO Wind Field
Date: 9010281200
16.7 ms-1
50
45
40
35
30
25
20
-50
-60
-70
-80

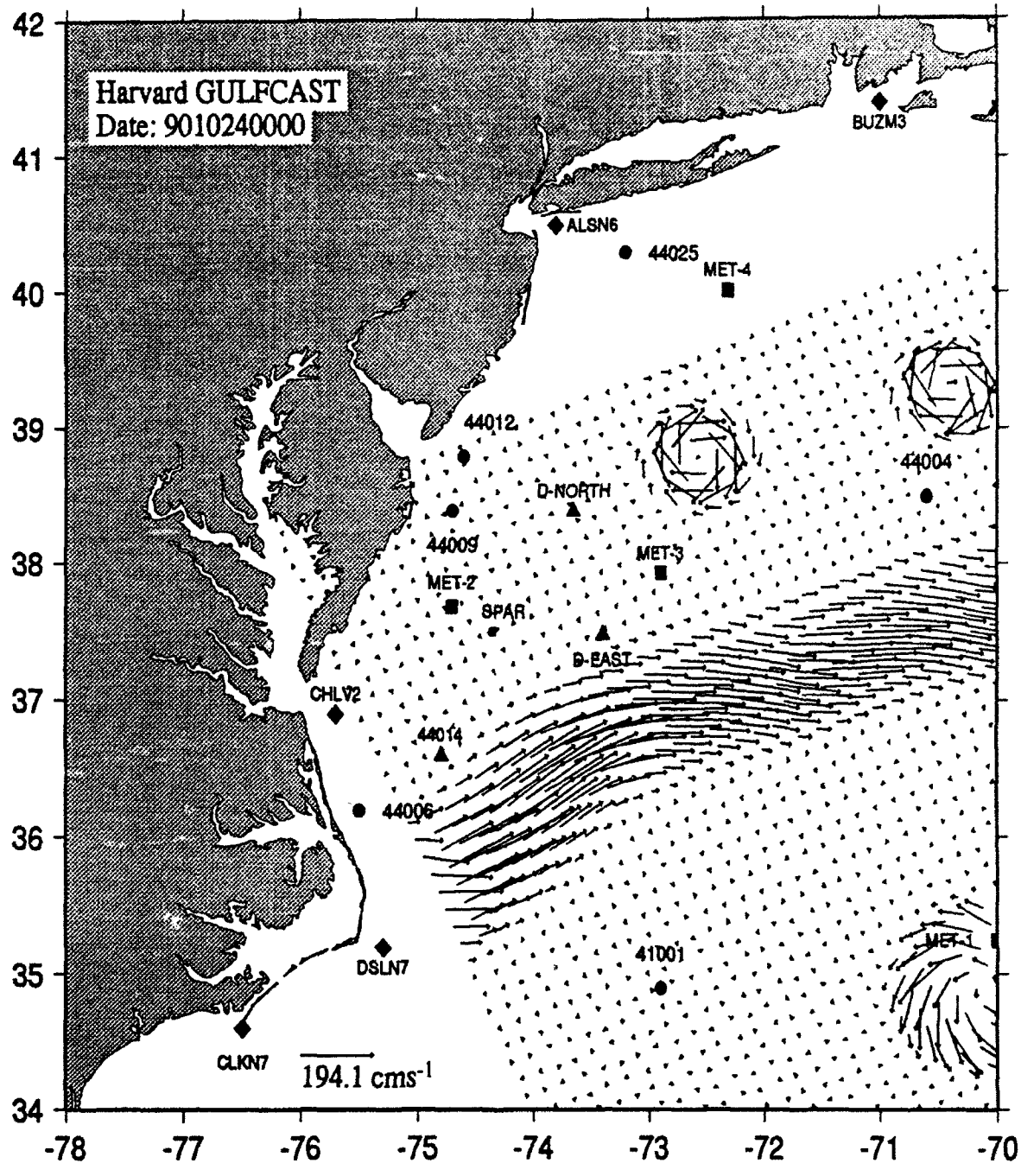
Appendix E: Custer Diagrams of Surface Current Fields

Daily maps of the surface current fields from the Harvard "GULFCAST" feature model are presented in this appendix beginning at 20 October 1990, 00:00 GMT to 31 October 1990, 00:00 GMT.


Harvard GULFCAST
Date: 9010210000
BUZM3
ALSN6
44025
MET-4
44012
44004
D-NORTH
44009
MET-3
MET-2
SPAR
D-EAST
CHLV2
44014
44006
DSLN7
41001
MET-1
CLKN7
221.6 cms-1
42
41
40
39
38
37
36
35
34
-78
-77
-76
-75
-74
-73
-72
-71
-70


Harvard GULFCAST
Date: 9010220000
BUZM3
ALSN6
44025
MET-4
44012
44004
D-NORTH
44009
MET-3
MET-2
SPAR
D-EAST
CHLV2
44014
44006
41001
MET-1
DSLN7
CLKN7
226.8 cms-1
42
41
40
39
38
37
36
35
34
-78
-77
-76
-75
-74
-73
-72
-71
-70


Harvard GULFCAST
Date: 9010230000
BUZM3
ALSN6
44025
MET-4
44012
44004
D-NORTH
44009
MET-3
MET-2
SPAR
D-EAST
CHLV2
44014
44006
DSLN7
41001
MET-1
CLKN7
237.4 cms-1
42
41
40
39
38
37
36
35
34
-78
-77
-76
-75
-74
-73
-72
-71
-70


Harvard GULFCAST
Date: 9010240000
BUZM3
ALSN6
44025
MET-4
44012
44004
D-NORTH
44009
MET-3
MET-2
SPAR
D-EAST
CHLV2
44014
44006
41001
MET-1
DSLN7
CLKN7
194.1 cms-1
42
41
40
39
38
37
36
35
34
-78
-77
-76
-75
-74
-73
-72
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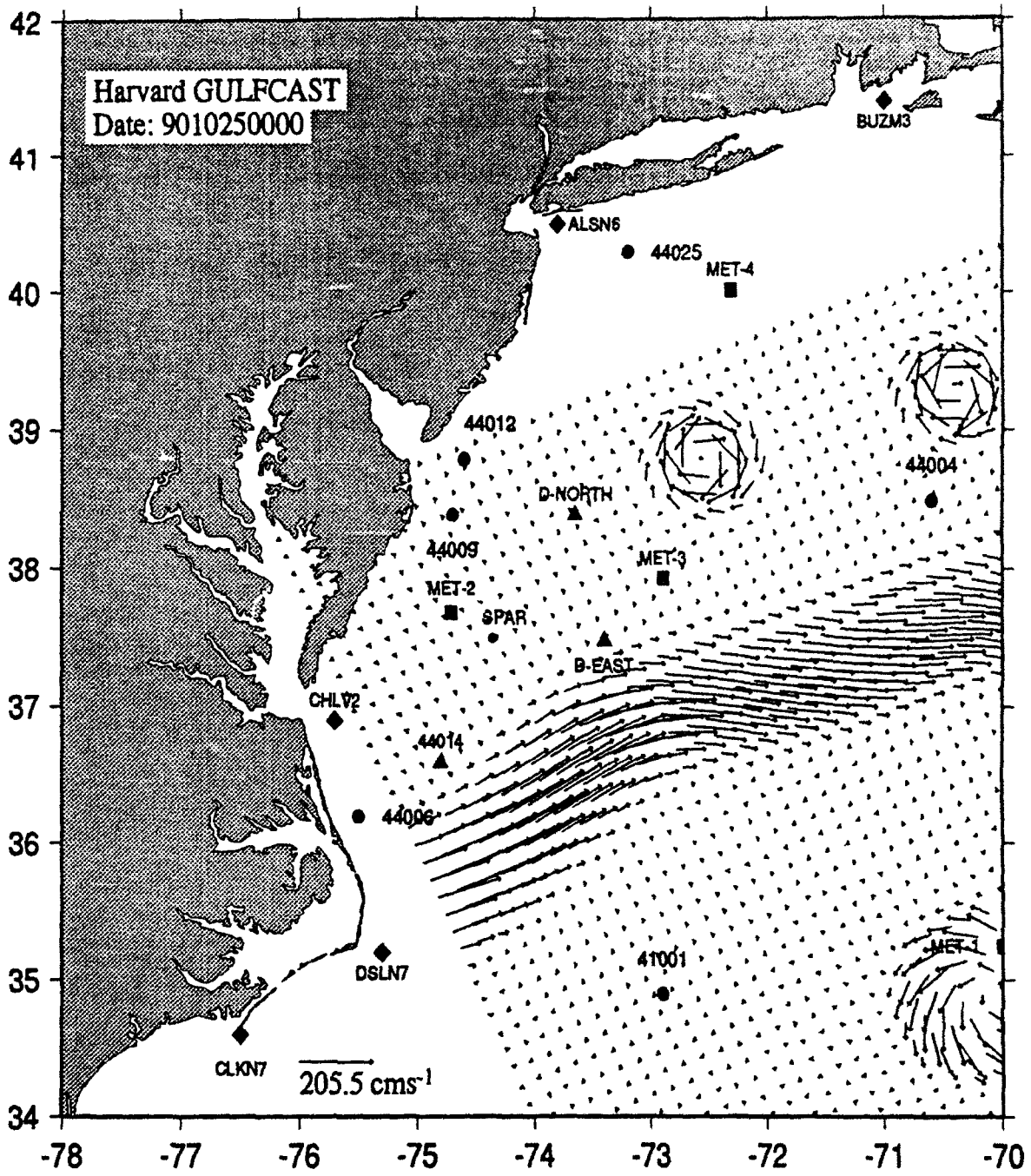
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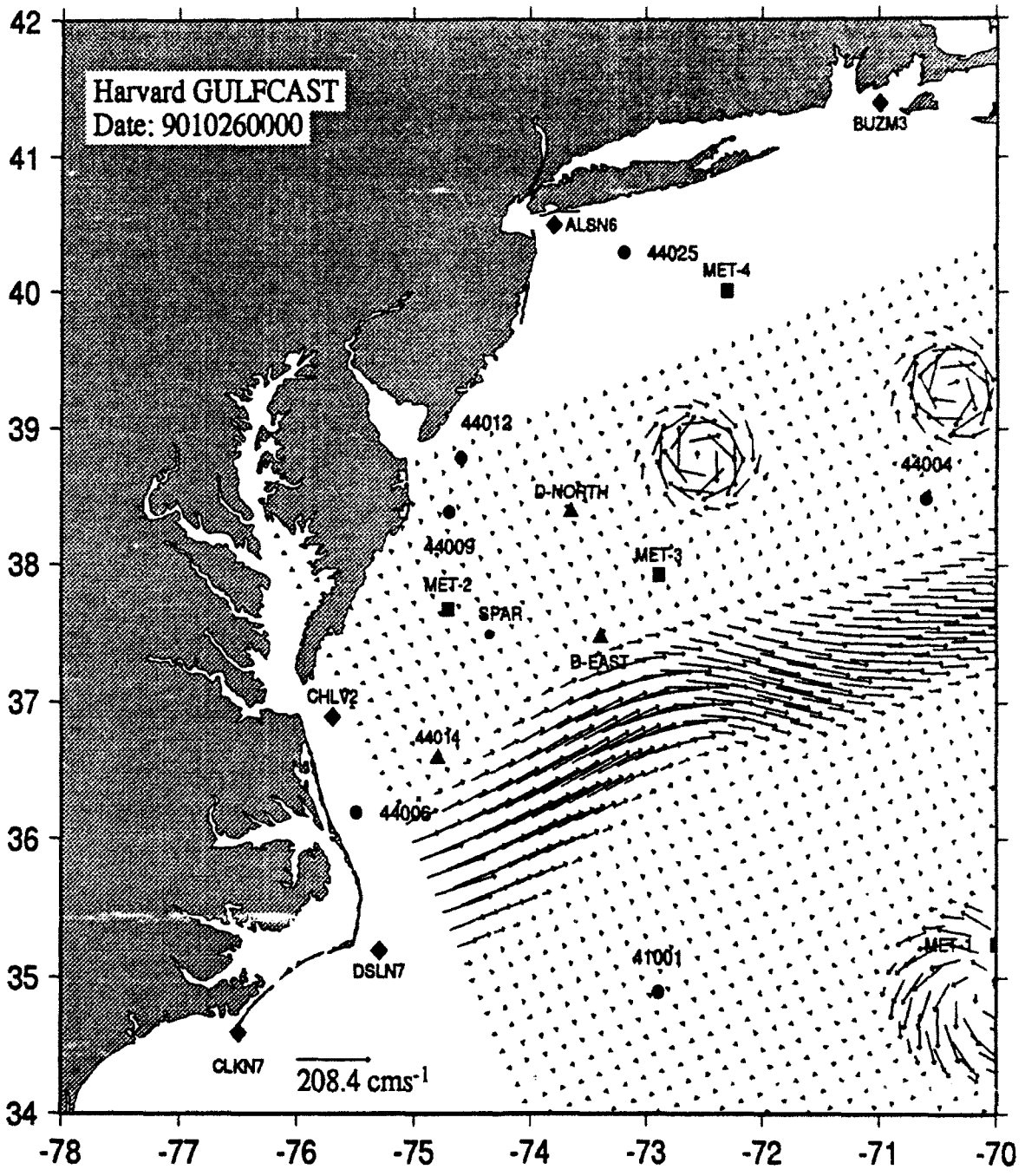
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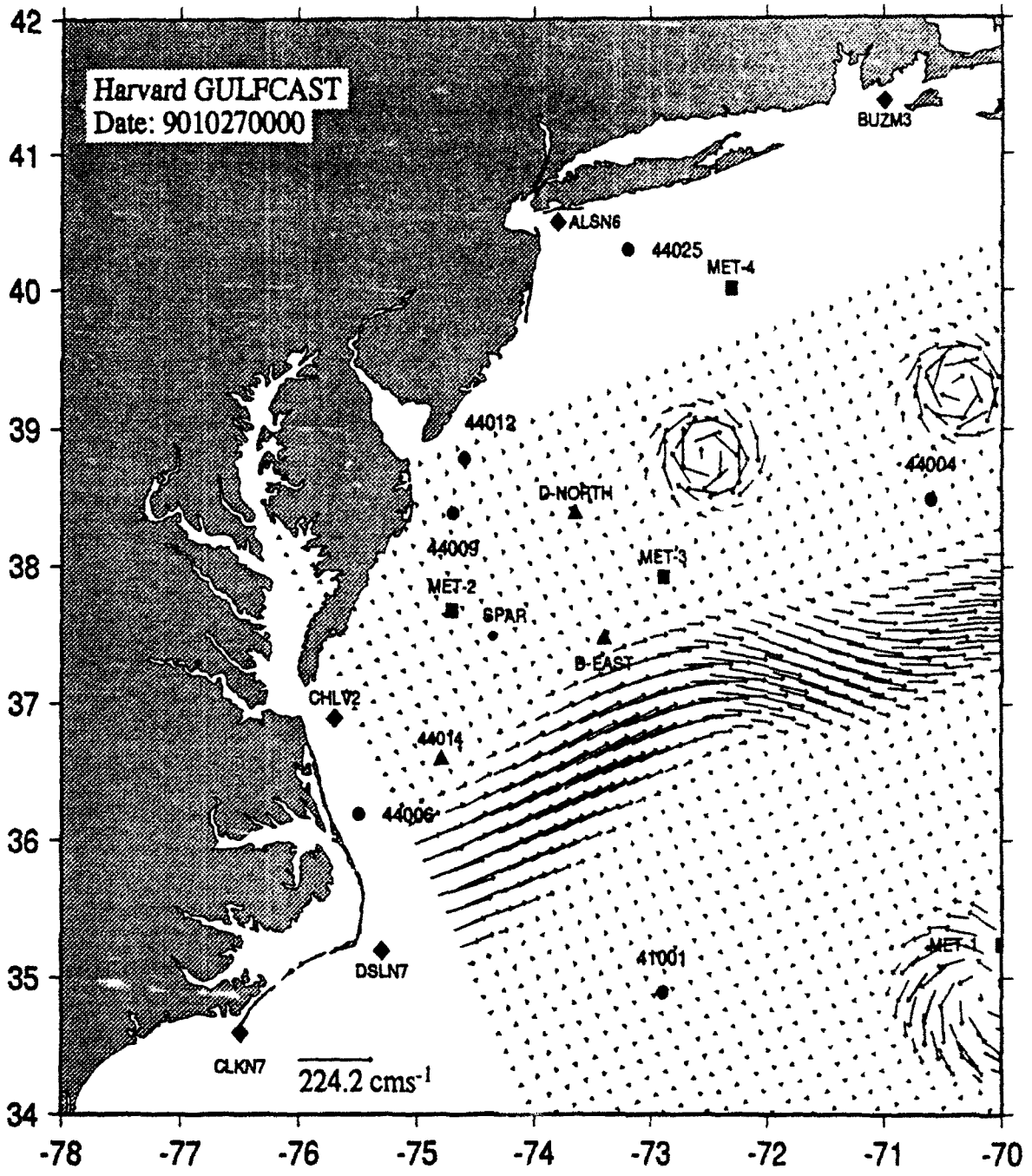
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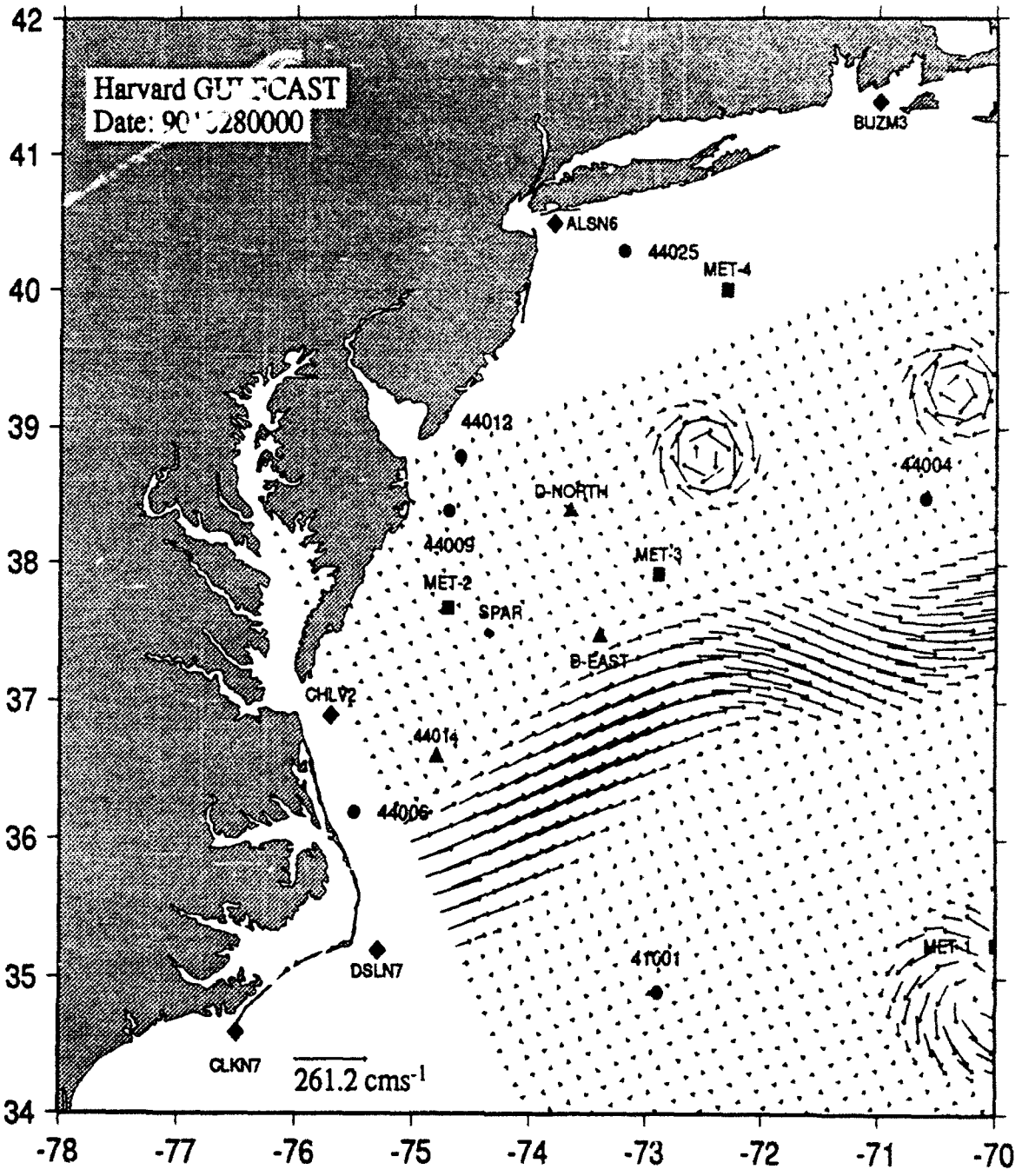
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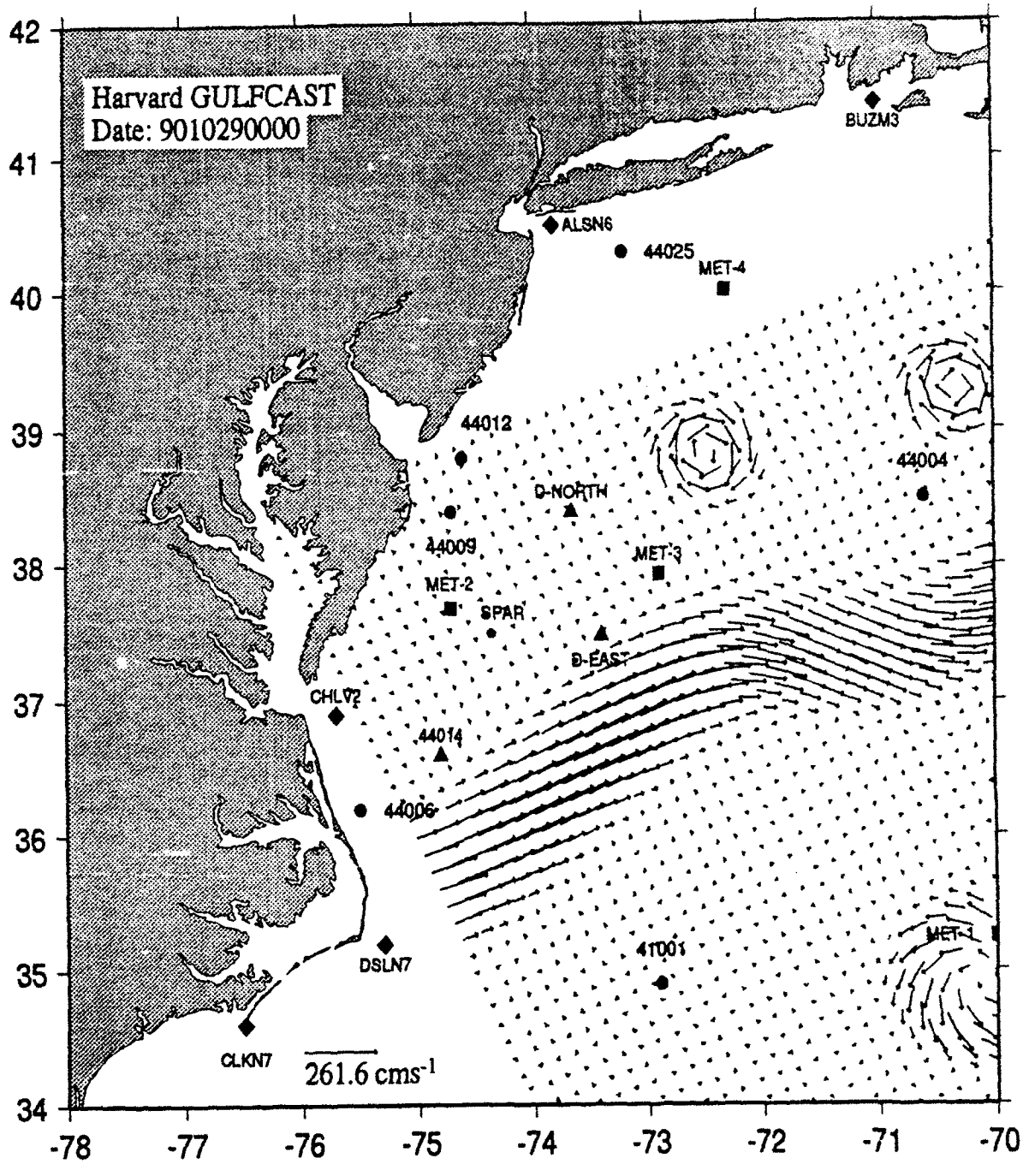
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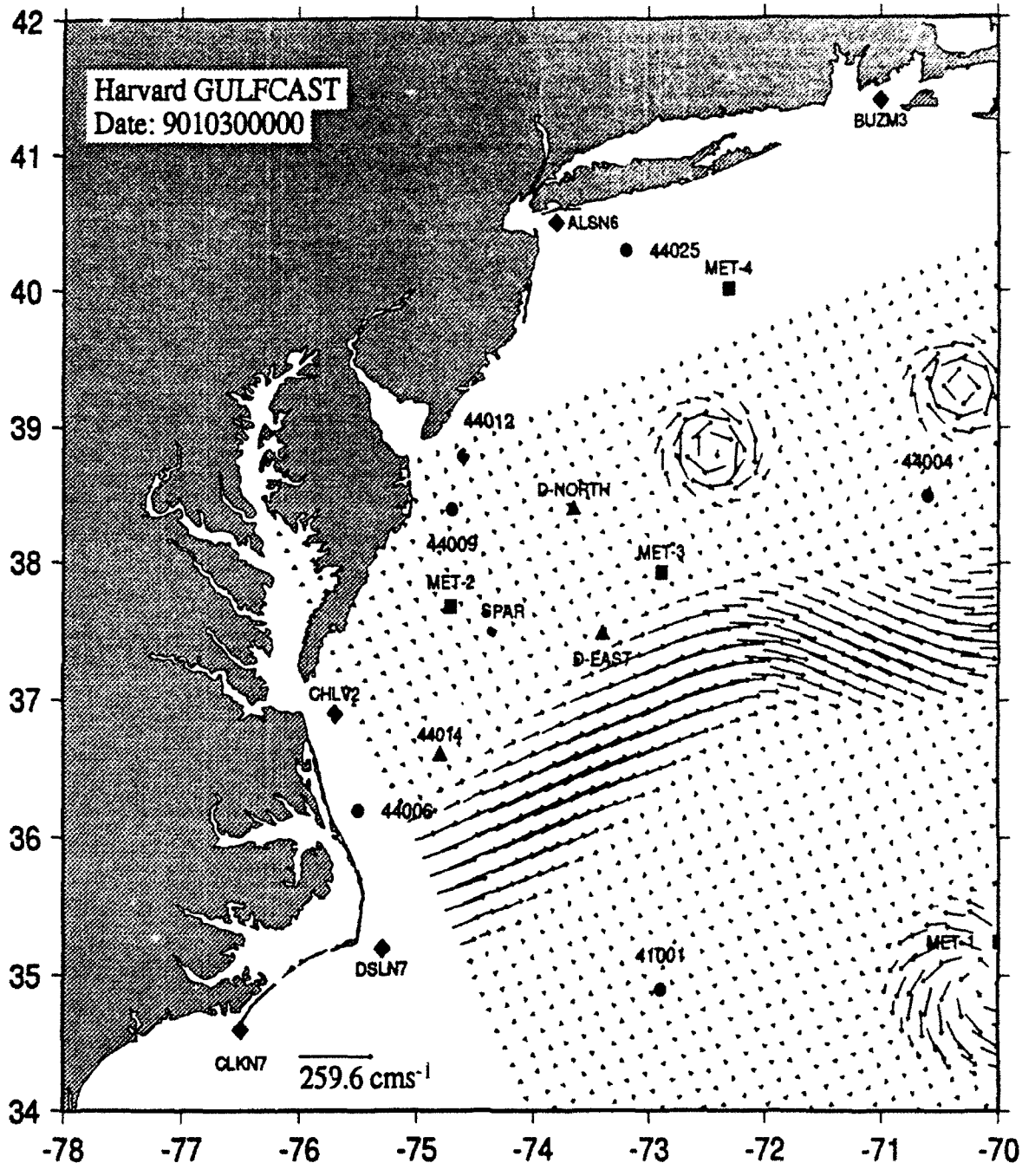
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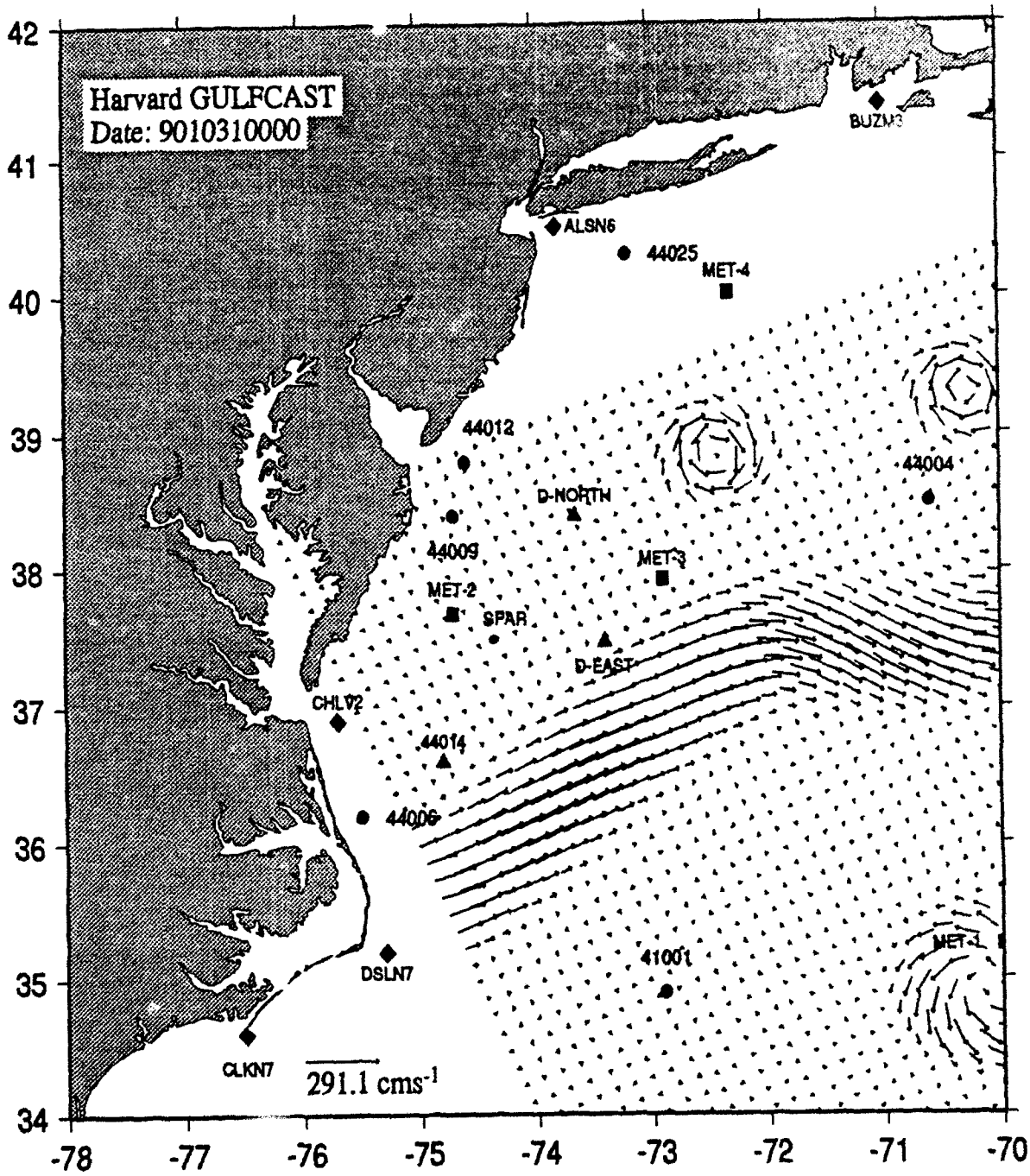
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This report describes the compiliation of observed and modelled wind and wave parameters during the first intensive observation period (IOP-1) from October 20-31, 1991, of the Surface Wave Dynamics Experiment. The measurements include wind speeds and directions, wave heights and periods, air and sea temperatures, and atmospheric pressures from three directional wave buoys, four meteorological buoys, and several routinely operated buoys from the National Data Buoy Center (NDBC). In addition, a summary of directional wave spectra is presented for this period. The model data include examples of wind fields from six numerical weather prediction models and the corresponding wave height maps as derived from the 3G-WAM ocean wave model. Estimated surface current velocities and directions from the Harvard quasi-geostrophic model are also presented for this time period.

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